

AMC PAMPHLET

AMCP 706-177

ENGINEERING DESIGN HANDBOOK

EXPLOSIVES SERIES

PROPERTIES OF EXPLOSIVES OF MILITARY INTEREST

HEADQUARTERS, U.S. ARMY MATERIEL COMMAND

JANUARY 1971

ABBREVIATIONS AND SYMBOLS

~	approximately. This symbol is used before numbers.
AC	Advisory Council on Scientific Research and Development, Great Britain.
ACS	American Chemical Society.
AISI	American Iron and Steel Institute.
Ann	Liebig's Annalen der Chemie.
Ann chim phys	Annales de chimie et de physique.
AP	armor-piercing.
APG	Aberdeen Proving Ground.
atm	atmosphere; atmospheric pressure.
Beil	Beilstein Organische Chemie, 4th Edition.
Ber	Berichte der Deutschen Chemischen Gesellschaft.
BIOS GP2-HEC	British Intelligence Overseas Service or Objective Subcommittee, Group 2, Halstead Exploiting Center.
BM	Bureau of Mines, United States Department of Interior.
Bull Soc chim	Bulletin de la société chimique de France.
CA	Chemical Abstracts.
calc	calculated.
Chem Met Eng	Chemical and Metallurgical Engineering.
Chim et Ind	Chimie et Industrie.
Comp rend	Comptes rendus hebdomadaires des séances de l'Académie des Sciences (Paris).
cp	centipoise.
CR	Comptes rendus hebdomadaires des séances de l'Académie des Sciences (Paris).
dec	decomposes.
ΔH	difference in heat (i.e., heat evolved) by decomposition.
DRP	Deutsches Reichspatent.
E	modulus of elasticity or "Young's modulus"; longitudinal stress/change in length; (force/area)/(elongation/length); expressed in lb/inch ² .
E'	same as E, but expressed in dynes/cm ² .
Gazz chim ital	Gazzetta Chimica Italiana.
GP	general purpose.
HE	high explosive.
HEAT	high explosive antitank.
Ind Eng Chem	Industrial & Engineering Chemistry.
J Am Chem Soc	Journal of the American Chemical Society
J Chem Ind	The Journal of the Society of Chemical Industry (London).
J Chem Soc	Journal of the Chemical Society (London).
J Frank Inst	Journal of the Franklin Institute.
J Ind Explosives Soc	Journal of the Industrial Explosives Society (Japan).
J prakt Chem	Journal für praktische Chemie.
LA	lead azide
Land-Bornst	Landolt-Bornstein Physikalisch-Chemische Tabellen, 5th Edition (Berlin).
M	molar.
M	Monatshefte für Chemie (Wein).
Mém poudr	Mémorial des poudres et salpêtres (Paris).
mg	milligram.

ABBREVIATIONS AND SYMBOLS (cont'd)

min	minimum.
ml	milliliter.
m/s	meters per second.
MW	molecular weight.
NAVORD	Bureau of Ordnance (U. S. Navy)
NC	nitrocellulose.
n_D^{20}	index of refraction, with D band of sodium as light source, at twenty degrees centigrade.
NDRC	National Defense Research Committee.
NFOC	National Fireworks Ordnance Corporation.
NG	nitroglycerin.
NOL	U. S. Naval Ordnance Laboratory, White Oak, Silver Spring, Maryland.
NOTS	U. S. Naval Ordnance Test Station, China Lake, Calif.
NRC	National Research Council.
OB	oxygen balance.
OCM	Ordnance Committee Minutes.
OSRD	Office of Scientific Research and Development
PA	Picatinny Arsenal.
PATR	Picatinny Arsenal Technical Report.
Phil Trans	Philosophical Transactions of the Royal Society of London.
Pogg Ann	Poggendorf's Annalen der Physik.
Proc Roy Soc	Proceedings of the Royal Society of London.
Rec trav chim	Recueil des travaux chimiques des Pays-Bas.
RH	relative humidity.
RI	Report of Investigation.
SAE	Society of Automotive Engineers.
SAP	semi-armor-piercing.
sol	solution.
Spec	Specifications.
std dev	standard deviation.
TM	Technical Manual, Department of the Army.
TM/TO	joint publication, as a TM and as a Department of the Air Force Technical Order.
Trans Farad Soc	Transactions of the Faraday Society
vac stab	vacuum stability.
Z angew Chem	Zeitschrift für angewandte Chemie.
Z anorg Chem	Zeitschrift für anorganische und allgemeine Chemie.
Z ges Schiess- Sprengstoffw	Zeitschrift für das gesamte Schiess und Sprengstoff- wesen (Munich).
Z/sec	atoms of oxygen per second.

AMCP 706-177

PREFACE

The Engineering Design Handbook Series of the Army Materiel Command is a coordinated series of handbooks containing basic information and fundamental data useful in the design and development of Army materiel and systems. The handbooks are authoritative reference books of practical information and quantitative facts helpful in the design and development of Army materiel so that it will meet the tactical and technical needs of the Armed Forces.

AMCP 706-177, *Properties of Explosives of Military Interest*, is one of a series on Explosives. One hundred and ten explosive compounds or mixtures are listed herein, alphabetically, with their properties, including composition variations. These explosives were selected because of their current or probable application to military use.

The tabulated data reflect the results of tests, and were first compiled for publication at Picatinny Arsenal, Dover, New Jersey, by W. R. Tomlinson, Jr. These data were later revised by Oliver E. Sheffield, also of Picatinny Arsenal, for the Engineering Handbook Office of Duke University, prime contractor to the Army Materiel Command.

The Handbooks are readily available to all elements of AMC, including personnel and contractors having a need and/or requirement. The Army Materiel Command policy is to release these Engineering Design Handbooks to other DOD activities and their contractors and to other Government agencies in accordance with current Army Regulation 70-31, dated 9 September 1966. Procedures for acquiring these Handbooks follow:

a. Activities within AMC and other DOD agencies order direct on an official form from:

Commanding Officer
Letterkenny Army Depot, ATTN: AMXLE-ATD
Chambersburg, Pennsylvania 17201

b. Contractors who have Department of Defense contracts should submit their requests through their contracting officer with proper justification to the address listed in par. a.

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U. S. Army Materiel Command
ATTN: AMCRD-TV
Washington, D. C. 20315

e. All foreign requests must be submitted through the Washington, D. C. Embassy to:

Assistant Chief of Staff for Intelligence
Foreign Liaison Office
Department of the Army
Washington, D. C. 20310

All requests, other than those originating within DOD, must be accompanied by a *valid justification*.

Comments and suggestions on this handbook are welcomed and should be addressed to Army Research Office-Durham, Box CM, Duke Station, Durham, North Carolina 27706.

HEADQUARTERS
UNITED STATES ARMY MATERIEL COMMAND
WASHINGTON, D. C. 20315

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ENGINEERING DESIGN HANDBOOK
PROPERTIES OF EXPLOSIVES OF MILITARY INTEREST

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PROPERTIES OF EXPLOSIVES OF MILITARY INTEREST

INTRODUCTION

1. PREDOMINANTLY A REPORT OF STANDARD TESTS. No effort was made to cover all the existing literature, either open or classified security information, on any explosive. Rather, the main resource has been reports from facilities using standard or well-known test procedures.

2. ORIGIN. Compilation of data resulting in this handbook was undertaken by Picatinny Arsenal personnel who desired to provide a manual tabulating the characteristics of explosives, based on tests, with regard to current, and possible future, interest. The first resulting Picatinny Arsenal publication was dated 20 June 1949. Revision 1, PA Technical Report No. 1740, dated April 1958, with revisions, provides the data used herein.

3. SCOPE. Tabulated data of tests on one hundred and ten explosive compounds or mixtures include sensitivity to friction, impact, heat; performance characteristics or effectiveness in weapons; physical and chemical properties; and method of preparation, synthesis or manufacture, with comments on historical origin, and supplementary references.

4. REFERENCE NOTATIONS AND SOURCES. The references, as to sources of data or for more details in methods of testing, have been listed, when available, at the end of each section devoted to a given explosive compound, explosive mixture, or explosive ingredient. Where no reference is given, it can be assumed that these data represent typical values obtained by standard procedures. When available any reference should be consulted for more details in interpreting test data.

Also there are listed Picatinny Arsenal Technical Reports which contain additional information on the particular explosive. These report numbers are given in ascending order, in columns corresponding to their terminal digits, and in accordance with the "Uniterm Index" prepared for Picatinny Arsenal by Documentation Incorporated under Contract DAI-36-034-501-ORD-(P)-42 (1955).

5. EXPLANATION OF TERMS AND METHODS OF TESTING. Data are tabulated herein on three form-type pages, in the following sequence of headings. Many of these terms are self-explanatory.

a. First tabular page.

(1) Name of the explosive in each instance.

(2) "Composition."

(3) "Impact Sensitivity, 2 Kg Wt."

(a) Impact sensitivity test for solids. (a)*

A sample (approximately 0.02 gram) of explosive is subjected to the action of a falling weight, usually 2 kilograms. A 20-milligram sample of explosive is always used in the Bureau of Mines (BM) apparatus when testing solid explosives. The weight of sample used in the Picatinny Arsenal (PA) apparatus is indicated in each case. The impact test value is the minimum

*Reference publications (a through q), applying to this introduction, are listed at the end of the introduction.

height at which at least one of 10 trials results in explosion. For the BM apparatus, the unit of height is the centimeter; for the PA apparatus, it is the inch. In the former, the explosive is held between two flat, parallel hardened ($C 63 \pm 2$) steel surfaces; in the latter case, it is placed in the depression of a small steel die-cup, capped by a thin brass cover, in the center of which is placed a slotted-vented-cylindrical steel plug, slotted side down. In the BM apparatus, the impact impulse is transmitted to the sample by the upper flat surface, in the PA, by the vented plug. The main differences between the two tests are that the PA test (1) involves greater confinement, (2) distributes the translational impulse over a smaller area (due to the inclined sides of the die-cup cavity), and (3) involves a frictional component (against the inclined sides).

The test value obtained with the PA apparatus depends, to a marked degree, on the sample density. This value indicates the hazard to be expected on subjecting the particular sample to an impact blow, but is of value in assessing a material's inherent sensitivity only if the apparent density (charge weight) is recorded along with the impact test value. The values tabulated herein were obtained on material screened between 50 and 100 mesh, U. S. Standard Screens where single component explosives are involved, and through 50 mesh for the mixtures.

(b) Impact sensitivity test for liquids. (b)

The PA Impact Test for liquids is run in the same way as for solids. The die-cup is filled and the top of the liquid meniscus adjusted to coincide with the plane of the top rim of the die-cup. To date, this visual observation has been found adequate to assure that the liquid does not wet the die-cup rim after the brass cap has been set in place. Thus far the reproducibility of data obtained in this way indicate that variations in sample size obtained are not significant.

In the case of the BM apparatus, the procedure that was described for solids is used with the following variations:

1. The weight of explosive tested is 0.007-gm.

2. A disc of desiccated filter paper (Whatman No. 1) 9.5-millimeter diameter, is laid on each drop, on the anvil, and then the plunger is lowered on the sample absorbed in the filter paper.

(4) "Friction Pendulum Test." (c)

A 7.0-gm sample of explosive, 50-100 mesh, is exposed to the action of a steel, or fiber, shoe swinging as a pendulum at the end of a long steel rod. The behavior of the sample is described qualitatively to indicate its reaction to this experience, i.e., the most energetic reaction is explosion, and in decreasing order of severity of reaction: snaps, cracks, and unaffected.

(5) "Rifle Bullet Impact Test." (d)

Approximately 0.5-pound of explosive is loaded in the same manner as it is loaded for actual use: that is, cast, pressed, or liquid in a 3-inch pipe nipple (2-inch inside diameter, 1/16-inch wall) closed on each end by a cap. The loaded item, in the standard test, contains a small air space which can, if desired, be filled by inserting a wax plug. The loaded item is subjected to the impact of a caliber .30 bullet fired perpendicularly to the long axis of the pipe nipple, from a distance of 90 feet.

(6) "Explosion Temperature." (a)

A 0.02-gm sample (0.01-gm in the case of initiators) of explosive, loose loaded in a No. 8 blasting cap, is immersed for a short period in a Wood's metal bath. The temperature determined is that which produces explosion, ignition or decomposition of the sample in 5 seconds, and the behavior of the sample is indicated by "Explodes" or "Ignites" or "Decomposes" placed beside the value. Where values were available for times other than 5 seconds, these have been included. For 0.1-second values, no cap was used, but the explosive was placed directly on Wood's metal bath, immediately after cleaning. The value 0.1 second is estimated, not determined, and represents an interval regarded as instantaneous to the observer's eye. Dashes indicate no action.

(7) "75°C International Heat Test." (a)

A 10-gm sample is heated for 48 hours at 75°C. The sample after this exposure is observed for signs of decomposition or volatility.

(8) "100°C Heat Test." (a)

A 0.6-gm sample is heated for two 48-hour periods at 100°C. It is also noted whether exposure at 100°C for 100 hours results in explosion.

(9) "Flammability Index." (h)

The measure of the likelihood that a bare charge will catch fire when exposed to flames is the index of flammability. The test is made by bringing an oxyhydrogen flame to bear on the explosive. The maximum time of exposure which gives no ignition in 10 trials and the minimum exposure which gives ignition in each of 10 trials are determined. The index of flammability is 100 divided by the mean of the two times in seconds. The most flammable substances have high indices, e.g., 250.

(10) "Hygroscopicity."

A 5- to 10-gm sample is exposed for hygroscopicity under the stated conditions, until equilibrium is attained, or in cases where either the rate is extremely low, or very large amounts of water are picked up, for the stated time. The sample, if solid, is prepared by sieving through a 50 and on a 100 mesh screen.

(11) "Volatility."

A 10-gm sample is exposed for volatility under the stated conditions. The sample if solid is prepared by sieving through a 50 and on a 100 mesh sieve.

(12) "Molecular Weight."

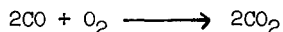
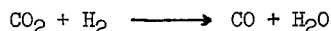
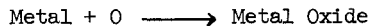
The molecular weight (MW) of a mixture can be calculated from the equation

$$\text{MW of mixture} = \frac{100}{\frac{a}{\text{mw}_1} + \frac{b}{\text{mw}_2} + \frac{c}{\text{mw}_3} + \frac{n}{\text{mw}_n}}$$

where a, b, c and n are the weight percents of the components, and mw₁, mw₂, mw₃ and mw_n their corresponding molecular weights.

(13) "Oxygen Balance."

The oxygen balance (OB) is calculated from the empirical formula of a compound in percentage of oxygen required for complete conversion of carbon to carbon dioxide (or carbon monoxide) and hydrogen to water. When metal is present the reactions are assumed to occur in the following order:



Procedure for calculating oxygen balance is to determine the number of gramatoms of oxygen which are excess or deficient for 100 grams of a compound. This number multiplied by the atomic weight of oxygen gives

$$\text{the oxygen balance: } 1600 \left(2X + \frac{Y}{2} - Z \right)$$

\div molecular weight of compound = oxygen balance to CO_2 and H_2O , where X = atoms of carbon, Y = atoms of hydrogen, Z = atoms of oxygen. The oxygen balance of a mixture is equal to the sum of the percent composition times the oxygen balance for each component.

The carbon/hydrogen (C/H) ratio is calculated as follows:

$$\frac{\text{Number of C atoms } (\%C + \%H)}{\text{Number of H atoms } (100)} = \text{C/H ratio}$$

(14) "Density."

(15) "Melting Point."

(16) "Freezing Point."

(17) "Boiling Point."

(18) "Refractive Index."

(19) "Vacuum Stability Test." (a)

A 5.0-gm sample (1.0 gm for initiators), after having been carefully dried, is heated for 40 hours, in vacuo at the desired temperature.

(20) "200 Gram Bomb Sand Test."

(a) Sand test for solids. (a)

A 0.4-gm sample of explosive, pressed at 3000 pounds per square inch into a No. 6 cap, is initiated by lead azide, or mercury fulminate (or, if necessary, by lead azide and tetryl), in a sand test bomb containing 200 gm of "on 30 mesh" Ottawa sand. The amount of azide, or of tetryl, that must be used, to insure that the sample crushes the maximum net weight of sand, is designated as its sensitivity to initiation and the net weight of sand crushed, finer than

30 mesh, is termed the sand test value. The net weight of sand crushed is obtained by subtracting from the total the amount crushed by the initiator when shot alone.

(b) Sand test for liquids. (b)

The sand test for liquids is made in accordance with the procedure given for solids except that the following procedure for loading the test samples is substituted:

Cut the closed end from a No. 6 blasting cap and load one end of the resulting cylinder with 0.20 gm of lead azide and 0.25 gm of tetryl, using a pressure of 3000 psi for consolidating each charge. With a pin, prick the powder train in one end of a piece of miner's black powder fuse 8 or 9 inches long. Crimp to the pricked end a loaded cylinder, taking care that the end of the fuse is held firmly against the charge in the cap. Crimp near the mouth of the cap so as to avoid squeezing the charge. Transfer a weighed portion of 0.400 gm of the test explosive to an aluminum cap, taking precautions when the explosive is liquid to insert the sample in such a manner that as little as possible adheres to the side walls of the cap, and when a solid material is being tested use material fine enough to pass through a No. 100 U. S. Standard Sieve. The caps used shall be of the following dimensions: length 2.00 inches, internal diameter 0.248-inch, wall thickness 0.025-inch. Press solid explosives, after insertion into the aluminum cap, by means of hand pressure to an apparent density of approximately 1.2 gm per cubic centimeter. This was done by exerting hand pressure on a wooden plunger until the plunger had entered the cap to a depth of 3.93 centimeters. Following are the dimensions of the interior of the cap: height 5.00 cm, area of cross section 0.312 square centimeters. Insert the cylinder containing the fuse and explosive charge of tetryl and lead azide into the aluminum cap containing the test explosive for the determination of sand crushed.

(21) "Sensitivity to Initiation."

This is sensitivity to initiation as described under the preceding heading. The minimum detonating charge, in grams, required to detonate the explosive sample, is given.

(22) "Ballistic Mortar, % TNT." (e)

The amount of sample under test which is necessary to raise the heavy ballistic mortar to the same height to which it is raised by 10 gm of trinitrotoluene (TNT) is determined. The sample is then rated, on a proportionate basis, as having a certain TNT value, i.e., as being a certain percent as effective as TNT in this respect. The formula is

$$\text{TNT value} = \frac{10}{\text{sample weight}} \times 100.$$

The ballistic mortar consists of a long compound supporting rod, at the end of which is supported a heavy short-nosed mortar. The mortar contains a chamber about 6 inches in diameter and 1 foot long. A projectile occupies about 7 inches of the chamber and the sample to be tested occupies a small portion of the remainder of the chamber. When the sample is detonated, the projectile is driven into a sand bank, and the mortar swings through an angle which is marked on paper by a pencil attached to the mortar. The angle thus indicates the height to which the pendulum is raised by the explosion, and this latter represents the energy measured by this test procedure.

(23) "Trauzl Test, % TNT." (d)

A sample of the explosive to be tested (of the order of 10 gm) is exploded in a cavity, or borehole, 25-mm in diameter and 125-mm deep, in a lead block 200-mm in diameter and 200-mm in height. The borehole is made centrally in the upper face of each block, which is cast in a mold from desilverized lead of the best quality. Although these tests have been made under a variety

of conditions, where possible the data have been taken from or related to those of Reference f (Naoum). Here a No. 8 blasting cap was used for initiation of the sample contained in glass. The weight of sample used was adjusted to give, with the initiator, a total expansion of 250 to 300 cc, since within this range expansion and sample weight were linearly related under the conditions of Naoum's test. Thus expansions for equivalent weights were readily calculated, and the test value expressed in percent of the expansion of an equivalent weight of TNT.

(24) "Plate Dent Test." (d)

Two methods were used for plate dent tests.

(a) Method A - The charge is contained in a copper tube, having an internal diameter of 3/4-inch and 1/16-inch wall. This loaded tube is placed vertically on a square piece of cold-rolled steel plate, 5/8-inch thick; 4-inch and 3-1/4-inch square plate gave the same results. The steel plate is in a horizontal position and rests in turn on a short length of heavy steel tubing 1-1/2 inches ID and 3 inches OD. The charge rests on the center of the plate, and the centers of the charge, plate, and supporting tube are in the same line. A 20-gm charge of the explosive under test is boosted by a 5-gm pellet of tetryl, in turn initiated by a No. 8 detonator.

(b) Method B - A 1-5/8-inch diameter, 5-inch long uncased charge is fired on a 1-3/4-inch thick, 5-square inch cold-rolled steel plate, with one or more similar plates as backing. The charge is initiated with a No. 8 detonator and two 1-5/8-inch diameter, 30-gm tetryl boosters.

Plate dent test value, or relative brisance = $\frac{\text{Sample Dent Depth}}{\text{Dent Depth for TNT at 1.61 gm/cc}} \times 100.$

(25) "Detonation Rate." (g)

The detonation rates reported in the tables contained herein were determined principally by using the rotating drum camera, under the conditions stated, e.g., usually charges 1 inch in diameter, 20 inches long, wrapped in cellulose acetate sheet, and initiated by a system designed to produce high order stable detonation at the maximum rate under the particular conditions. A typical initiating system for this consisted of four tetryl pellets 0.995 inch in diameter, 0.75 inch long, pressed to 1.50 gm/cc, with a Corps of Engineers special blasting cap placed in a central hole in the end pellet.

b. Second tabular page.

(1) "Booster Sensitivity Test." (p)

The booster sensitivity test procedure is a scaled up modification of the Bruceton method (unconfined charge). The source of the shock consists of two tetryl pellets, each 1.57 inches diameter by 1.60 inches high, of approximately 100 gm total weight. The initial shock is degraded through wax spacers of cast Acrawax B, 1-5/8 inches diameter. The test charges are 1-5/8 inches diameter by 5 inches long. The value given is the thickness of wax in inches at the 50% detonation point. The weight of tetryl pellet noted is the minimum which will produce detonation with the spacer indicated.

(2) "Heat of" (calorimetric tests). (i)

Heats of combustion and explosion are generally determined on samples weighing of the order of 1 to 2 gm, in standard calorimeter bombs such as the Parr or Emerson, approximately 400 cc (for low loading density), or the Boas, approximately 45 cc (for high loading density). For

heats of combustion the sample is burned under about 40 atmospheres of oxygen; for heats of explosion, nitrogen, or one atmosphere of air is used.

- (3) "Specific Heat."
- (4) "Burning Rate."
- (5) "Thermal Conductivity."
- (6) "Coefficient of Expansion."
- (7) "Hardness, Mohs' Scale."
- (8) "Young's Modulus."
- (9) "Compressive Strength."
- (10) "Vapor Pressure."
- (11) "Decomposition Equation."
- (12) "Armor Plate Impact Test." (j)
- (a) 60-mm Mortar Projectile.

A modified 60-mm, M49A2, mortar projectile is loaded with the explosive to be tested, drilled to the proper depth (about 1/2 inch), and a flat-based steel plug screwed into the projectile to give a smooth close-fit between the plug base and the charge. The part of the plug outside the projectile is rounded off in the form of a spherical section. The loaded projectile with fins attached is fired from a five foot length of 2-3/8 inches ID x 3-3/8 inches OD Shelby steel tubing. The igniter and propelling charge, consisting of an igniter for a 2.36-inch rocket (bazooka), 5 gm of 4F black powder, and a quantity of shotgun propellant sufficient to give the desired velocity (read from a calibration chart) are conveniently loaded into the "gun" through a simple breech plug. The velocities are measured electronically, and the reaction, inert or affected, is determined by observation (e.g., whether or not flash occurs on impact). Within the range of flight stability of the projectile, 200-1100 ft/sec, the 50% point is located.

- (b) 500-lb General Purpose Bombs.

- (13) "Bomb Drop Test."

Bomb drops are made using bombs assembled in the conventional manner, as for service usage, but containing either inert or simulated fuzes. The target is usually reinforced concrete.

c. Third tabular page.

- (1) "Fragmentation Test." (1)

The weight of each empty projectile and weight of water displaced by the explosive charge is determined, and from this the specific gravity of the charge is calculated. All 3-inch and 90-mm projectiles are initiated by M20 Booster pellets, and those used with 3-inch HE, M42A1, Lot KC-5 and 90-mm HE, M71, Lot WC-91 projectiles are controlled in weight and height as follows: 22.50 \pm 0.10 gm, and 0.480 to 0.485 inch.

The projectile assembled with fuze, actuated by a Blasting Cap, Special, Type II (Spec 49-20) placed directly on a lead of comparable diameter, and booster, are placed in boxes constructed of half-inch pine. The 90-mm projectiles are fragmented in boxes 21 x 10-1/2 x 10-1/2 inches and the 3-inch projectiles in boxes 15 x 9 x 9 inches outside dimensions. The box with projectile is placed on about 4 feet of sand in a steel fragmentation tub, the detonator wires are connected, and the box covered with approximately 4 feet more of sand. The projectile is fired and the sand run onto a gyrating 4-mesh screen on which the fragments are recovered.

(2) "Fragment Velocity."

Charges 10-1/8 inches long and 2 inches in diameter, containing a booster cavity, filled by a 72-gm tetryl pellet (1-3/8 inches diameter, 2 inches long, average density 1.594) are fired in a model projectile of Shelby seamless tubing, 2 inches ID, 3 inches OD, SAE 1020 steel, with a welded-on cold rolled steel base. The projectile is so fired in a chamber, connected to a corridor containing velocity stations, that a desired wedge of projectile casing fragments can be observed. The fragment velocities are determined by shadow photographs, using flash bulbs, and rotating drum cameras, each behind three slits. The drum cameras have a writing speed of 30 meters per second.

(3) "Blast (Relative to TNT)."

The blast pressures and impulses given were determined almost exclusively with tourmaline gages, and the usual necessary specialized electrical circuits, shielded co-axial cables, oscillographs, etc. In general, the data represent results of tests with large cased charges.

(4) "Shaped Charge Effectiveness, TNT = 100." (k, m)

Unconfined charges 2 inches in diameter and 6 inches long, boosted by a 10-gm pressed tetryl pellet, set in a 20-mm pellet (truncated cone) of cast 60/40 cyclotol, are shot against 3-inch homogeneous armor plate at a 1-3/16 inches standoff. The cones used are commercial Pyrex glass funnels, sealed off at the start of the stem, 2 inches in diameter, 0.110 to 0.125 inch wall thickness.

Unconfined charges 1.63 inches in diameter and 6 inches long are tested at a standoff of 1.63 inches against stacks of 4 x 4 x 1 inch mild steel plates. M9Al steel cones are used. Results are averages of 4 trials.

(5) "Color."

(6) "Principal Uses."

(7) "Method of Loading."

(8) "Loading Density."

(9) "Storage."

Ammunition and bulk explosives in storage represent varying degrees of hazard and compatibility. This has led to their being divided into a number of hazard classes and compatibility groups as indicated in subparagraphs (b) and (c) below.

(a) Method: Wet or dry.

(b) Hazard Class (Quantity-Distance).

Ammunition and bulk explosives are divided into quantity-distance classes, Class 1 through 12, according to the damage expected if they explode or ignite (Reference: Army Materiel Command Regulation, AMCR 385-100, AMC Safety Manual, chapter 17). All standard explosives in bulk are included in four of these classes: Class 2, 2A, 9, and 12 (TM 9-1910/TO 11A-1-34).

(c) Compatibility Group.

Explosives and ammunition are grouped for compatibility with respect to the following factors:

1. Effects of explosion of the item.
2. Rate of deterioration.
3. Sensitivity to initiation.
4. Type of packing.
5. Effects of fire involving the item.
6. Quantity of explosive per unit.

(d) Exudation.

d. Miscellaneous entries.

Where available and appropriate, the following or related data are given, in space at the bottom of the third form, or on plain pages.

- (1) Solubility.
- (2) Methods of manufacture.
- (3) Historical information.
- (4) Bulk compressibility modulus. (q)

The direct experimental measurement of the dynamic bulk modulus of a solid is difficult, and few such measurements have been made. One apparatus has been developed at the Naval Ordnance Laboratory and is described in detail in Reference q. Bulk modulus (its reciprocal is the compressibility) is defined as the ratio of stress to strain when the stress is a pressure applied equally on all surfaces of the sample and the strain is the resulting change in volume per unit volume.

(5) Hydrolysis tests. (o)

The 240-hour hydrolysis test is conducted as follows: A 5-gm sample of the dry nitrocellulose is weighed accurately in a tare-weighted 250-cc Pyrex flask having a ground glass connection for a Pyrex condenser. Then 100 cc of distilled water is added to the nitrocellulose in the flask and the flask fitted to the condenser. The flask is placed in a steam bath in which the water is kept boiling constantly by means of electric hotplates. At the end of 240 hours the amount of solid developed by the hydrolysis of the nitrocellulose is measured by an electrometric pH method.

(6) Sensitivity to initiation by electrostatic discharge. (n)

The samples are tested under two amounts of confinement, designated as unconfined and confined. In the unconfined test, a sample of approximately 0.05 gm is dumped into a shallow depression in a steel block and flattened out with a spatula. In the confined tests (partly confined), the sample of approximately 0.05 gm is introduced into soft-glass tube (~ 7 mm ID x 18 mm long) which fits over a metal peg. The volume of the space around the charge at zero gap is ~ 0.15 cc; at a gap of 0.6 mm, it is ~ 0.4 cc. In addition to providing moderate confinement, this system also minimizes dispersion of the sample by the test spark, and reduces the effect of material being repelled from the needle point by electrostatic field effect.

When a test is to be made, the needle point electrode is screwed up until the gap between electrodes is greater than the critical gap discharge at the test voltage. The sample is then placed in position, the high-voltage terminal of the charged condensor is switched to the point electrode by means of a mercury switch, and the electrode is screwed down until discharge occurs.

The spark energy (in joules), for zero probability of ignition, is determined.

(7) Destruction by chemical decomposition.

Burning is the preferred method of destroying explosives. Initiating type explosives (in quantity) are usually destroyed by detonation with demolition blocks. Destruction of explosives by chemical decomposition can be effectively used where small laboratory quantities are involved. Procedures given are standard for only lead azide, mercury fulminate and nitroglycerin.

(8) Other information.

(9) References.

6. REFERENCES CITED IN INTRODUCTION.¹

a. W. H. Rinkenbach and A. J. Clear, Standard Laboratory Procedures for Sensitivity, Brisance, and Stability of Explosives, PATR No. 1401, 18 March 1944, Revised 28 February 1950.

b. W. R. Tomlinson, Jr. and A. J. Clear, Development of Standard Tests -- Application of the Impact and Sand Tests to the Study of Nitroglycerin and Other Liquid Explosives, PATR No. 1738, 13 June 1949.

c. J. H. McIvor, Friction Pendulum, PA Testing Manual 7-1, 8 May 1950.

d. Departments of the Army and the Air Force Joint Technical Manual and Technical Order, TM 9-1910/TO 11A-1-34, Military Explosives, April 1955.

e. J. H. McIvor, Ballistic Mortar Test, PA Testing Manual 7-2, 8 May 1950.

f. Ph. Naoum, Z ges Schiess-Sprengstoffw, pp. 181, 229, 267 (27 June 1932).

g. G. J. Mueller, Equipment for the Study of the Detonation Process, PATR No. 1465, 4 July 1945.

h. NDRC Interim Report, Preparation and Testing of Explosives, Nos. PT-19 and PT-20, February-April 1944.

i. Linnie E. Newman, PA Chemical Laboratory Report Nos. 127815 and 134476, 11 January 1951.

j. Report AC-2983/Org Expl 179.

¹For information regarding source of references, inquiries should be made to the Commander, U.S. Army Research Office--Durham, ATTN: CRDARD-EH, Box CM, Duke Station, Durham, North Carolina 27706.

- k. Eastern Laboratory, du Pont, Investigation of Cavity Effect, Section III, Variation of Cavity Effect with Composition, NDRC Contract W-672-ORD-5723.
- l. J. H. McIvor, Fragmentation Test Procedures, PA Testing Manual 5-1, 24 August 1950.
- m. Eastern Laboratory, du Pont, Investigation of Cavity Effect, Final Report, 18 September 1943, NDRC Contract W-672-ORD-5723.
- n. F. W. Brown, D. H. Kusler, and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Department of Interior, Bureau of Mines, R. I. 3852, 1946.
- o. D. D. Sager, Study of Acid Adsorption and Hydrolysis of Cellulose Nitrate and Cellulose Sulphate, PATR No. 174, 12 January 1932.
- p. L. C. Smith and E. H. Eyster, Physical Testing of Explosives, Part III, Miscellaneous Sensitivity Tests, Performance Tests, OSRD Report No. 5746, 27 December 1945.
- q. C. S. Sandler, An Acoustic Technique for Measuring the Effective Dynamic Bulk Modulus of Elasticity and Associated Loss Factor of Rubber and Plastics, NAVORD Report No. 1524, 1 September 1950.
- W. S. Cramer, Bulk Compressibility Data on Several Explosives, NAVORD Report No. 4380, 15 September 1956.

AMCP 706-177

Amatol, 80/20

Composition: % Ammonium Nitrate 80 TNT 20 C/H Ratio	Molecular Weight: 92	
	Oxygen Balance: CO ₂ % +1 CO % +11	
	Density: gm/cc	Cast 1.46
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 90 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 15 Sample Wt, mg 17	Boiling Point: °C	
	Refractive Index, n_{20}^D n_{25}^D n_{30}^D	
	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.45 120°C 0.95 135°C 150°C 6.8	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	200 Gram Bomb Sand Test: Sand, gm 35.5	
Rifle Bullet Impact Test: 5 Trials % Explosions 0 Partial 0 Burned 0 Unaffected 100	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.07	
	Ballistic Mortar, % TNT: (a) 130	
	Trauzl Test, % TNT: (b) 123	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 280 10 15 20	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
75°C International Heat Test: % Loss in 48 Hrs 0.06	Detonation Rate: Confinement None None Condition Cast Cast Charge Diameter, in. 1.0 1.0 Density, gm/cc 1.46 1.50 Rate, meters/second 4500 5100	
100°C Heat Test: % Loss, 1st 48 Hrs 0.03 % Loss, 2nd 48 Hrs 0.05 Explosion in 100 Hrs None		
Flammability Index:		
Hygroscopicity: % 30°C, 90% RH, 2 days 61		
Volatility: Nil		

<p>Fragmentation Test:</p> <p>90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments: For TNT For Subject HE</p> <p>3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments: For TNT For Subject HE</p> <p>Fragment Velocity: ft/sec (f) At 9 ft 1900 At 25½ ft 1750 Density, gm/cc</p>	<p>Shaped Charge Effectiveness, TNT = 100:</p> <p>Glass Cones Steel Cones</p> <p>Hole Volume Hole Depth</p> <p>Color: Buff-yellow</p> <p>Principal Uses: Bombs, HE projectiles</p> <p>Method of Loading: Cast</p> <p>Loading Density: gm/cc 1.46</p> <p>Storage:</p> <p>Method Dry</p> <p>Hazard Class (Quantity-Distance) Class 9</p> <p>Compatibility Group Group I</p> <p>Exudation Does not exude at 65°C</p>
<p>Blast (Relative to TNT):</p> <p>Air: Peak Pressure Impulse Energy</p> <p>Air, Confined: Impulse</p> <p>Under Water: Peak Pressure Impulse Energy</p> <p>Underground: Peak Pressure Impulse Energy</p>	<p>Booster Sensitivity Test: (a)</p> <p>Condition Pressed</p> <p>Tetryl, gm 100</p> <p>Wax, in. for 50% Detonation 0.83</p> <p>Density, gm/cc 1.65</p> <p>Heat of: (d, e)</p> <p>Combustion, cal/gm 1002*</p> <p>Explosion, cal/gm 490*</p> <p>Gas Volume, cc/gm 930*</p> <p>*Calculated from composition of mixture.</p>

Composition: % Ammonium Nitrate 60 TNT 40 C/H Ratio	Molecular Weight: 108	
	Oxygen Balance: CO ₂ % -18 CO % + 2	
	Density: gm/cc	Cast 1.60
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 95 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 16 Sample Wt, mg 17	Boiling Point: °C	
	Refractive Index, n ₂₀ ^D n ₂₅ ^D n ₃₀ ^D	
	Friction Pendulum Test: Steel Shoe Fiber Shoe	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C	
	200 Gram Bomb Sand Test: Sand, gm 41.5	
	Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 270 10 15 20	
75°C International Heat Test: % Loss in 48 Hrs 100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.06	
	Ballistic Mortar, % TNT: (a) 128	
	Trauzl Test, % TNT:	
Flammability Index: Hygroscopicity: % Volatility: Nil	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
	Detonation Rate: Confinement None Condition Cast Charge Diameter, in. 1.0 Density, gm/cc 1.50 Rate, meters/second 5760	

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc 1.49 Charge Wt, lb 1.971 Total No. of Fragments: For TNT 703 For Subject HE 583 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc 1.57 Charge Wt, lb 0.827 Total No. of Fragments: For TNT 514 For Subject HE 408	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones Hole Volume Hole Depth
	Color: Buff-yellow
	Principal Uses: Bombs, HE projectiles
	Method of Loading: Cast
	Loading Density: gm/cc 160
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation Does not exude at 65°C
Blast (Relative to TNT): Air: Peak Pressure 95 Impulse 85 Energy 84 Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Heat of: (d, e) Combustion, cal/gm 1658* Explosion, cal/gm 633* Gas Volume, cc/gm 880*

*Calculated from composition of mixture.

Composition: % Ammonium Nitrate 50 TNT 50 C/H Ratio	Molecular Weight: 118	
	Oxygen Balance: CO ₂ % -27 CO % - 3	
	Density: gm/cc	Cast 1.59
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 95 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 16 Sample Wt, mg 17	Boiling Point: °C	
	Refractive Index, n_{20}^D n_{25}^D n_{30}^D	
	Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	
Rifle Bullet Impact Test: Trials % Explosions 0 Partial 0 Burned 0 Unaffected 100	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.2 120°C 1.0 135°C 150°C	
	200 Gram Bomb Sand Test: Sand, gm 42.5	
	Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 265 10 15 20	
	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.05	
	Ballistic Mortar, % TNT: (a) 124	
75°C International Heat Test: % Loss in 48 Hrs 100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Trauzl Test, % TNT:	
	Plate Dent Test: Method B Condition Cast Confined No Density, gm/cc 1.55 Brisance, % TNT 52	
	Detonation Rate: Confinement None None Condition Cast Cast Charge Diameter, in. 1.0 1.0 Density, gm/cc 1.55 1.55 Rate, meters/second 6430 6230	
	Flammability Index:	
	Hygroscopicity: % Nil	
	Volatility:	

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc 1.55 Charge Wt, lb 2.053 Total No. of Fragments: For TNT 703 For Subject HE 630 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc 1.54 Charge Wt, lb 0.819 Total No. of Fragments: For TNT 514 For Subject HE 385	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones (g) Hole Volume 53 Hole Depth 69
	Color: Buff-yellow
	Principal Uses: Bombs, HE projectiles
	Method of Loading: Cast
	Loading Density: gm/cc 1.59
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation Does not exude at 65°C
Blast (Relative to TNT): Air: Peak Pressure 97 Impulse 87 Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy 98 Underground: Peak Pressure 104 Impulse 104 Energy 104	Booster Sensitivity Test: (a) Condition Cast Tetryl, gm 100 Wax, in. for 50% Detonation 0.60 Density, gm/cc 1.55 Heat of: (d, e) Combustion, cal/gm 1990 Explosion, cal/gm 703* Gas Volume, cc/gm 855* *Calculated from composition of mixture. Specific Heat: cal/gm/°C (i) Temp, 20° to 80°C 0.383 Bomb Drop Test: T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete: Max Safe Drop, ft 4000-5000

Compatibility with Metals:

Dry - Metals unaffected are zinc, iron, tin, brass, brass tin plated, brass NRC coated, brass shellac coated, nickel aluminum, steel, steel plated with nickel, zinc or tin, stainless steel, Parkerized steel, and steel coated with acid-proof black paint. Metals slightly affected are copper, bronze, lead and copper plated steel.

Preparation:

In preparing amatols the proper granulation of ammonium nitrate is required if the maximum density of the cast amatol is desired. The ammonium nitrate should be dried so as to contain not more than 0.25% moisture. It should be heated to about 90°C before being added to the appropriate weight of molten TNT contained in a melting vessel equipped with an agitator. Continue mixing to insure uniformity and load by pouring into shell or bombs.

Origin:

Developed by the British during World War I in order to conserve TNT.

References:²

(a) L. C. Smith and E. H. Eyster, Physical Testing of Explosives, Part III, Miscellaneous Sensitivity Tests, Performance Tests, OSRD Report 5746, 27 December 1945.

(b) Report AC-17/Phys Ex 1.

(c) D. P. McDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(d) Committee of Div 2 and 8, NDRC, Report on HBX and Tritonal, OSRD Report No. 5406, 31 July 1945.

(e) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.

(f) R. W. Drake, Fragment Velocity and Panel Penetration of Several Explosives in Simulated Shells, OSRD Report No. 5622, 2 January 1946.

(g) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Final Report, 18 September 1943, NDRC Contract W-672-ORD-5723.

(h) Also see the following Picatinny Arsenal Technical Reports on Amatols:

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
240	681	132	743	364	65	266	1207	548	549
350	731	182	1173	694	425	556	1457	638	799
630	901	1302	1373	734	695	666	1797	838	929
950	1051	1352	1323	874	715	986	1827	1098	1129
1300	1311	1372	1493	1344	735	1376	2167	1148	1219
1530	1451	1552	1783		1145	1446		1388	1369
	1651				1225	1636		1568	1559
					1345	1796		1838	
					1455				
					1885				

(i) TM 9-1910/TO 11A-1-34, Military Explosives, April 1955.

²See footnote 1, page 10.

Composition: % Ammonium Nitrate 22 TNT 67 Aluminum 11 C/H Ratio	Molecular Weight: 102	
	Oxygen Balance: CO ₂ % -55 CO % -22	
	Density: gm/cc	Cast 1.65
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 91 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 11 Sample Wt, mg 19	Boiling Point: °C	
	Refractive Index, n_{20}^D n_{25}^D n_{30}^D	
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 4.4 135°C 150°C	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm 47.8	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 265 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.20 Lead Azide Tetryl	
	Ballistic Mortar, % TNT: (a) 122	
75°C International Heat Test: % Loss in 48 Hrs	Trauzl Test, % TNT:	
	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
100°C Heat Test: % Loss, 1st 48 Hrs 0.00 % Loss, 2nd 48 Hrs 0.10 Explosion in 100 Hrs None	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
Flammability Index:		
Hygroscopicity: %		
Volatility:		

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc 1.65 Charge Wt, lb Total No. of Fragments: For TNT 655 For Subject HE 550	Shaped Charge Effectiveness, TNT = 100: <div style="text-align: right;">Glass Cones Steel Cones</div> Hole Volume Hole Depth
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Color:
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy <u>Preparation:</u> Procedure same as described under Amatols, except aluminum is added to the ammonium nitrate-TNT molten mixture under agitation until uniformity in composition is obtained. Loading is accomplished by pouring into the appropriate projectile.	Principal Uses: Projectile filler
	Method of Loading: Cast
	Loading Density: gm/cc 1.65
	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Exudation
	<u>Origin:</u> Castable mixture developed in United States during World War I. <u>References:</u> (a) W. R. Tomlinson, Jr., <u>Physical and Explosive Properties of Military Explosives</u> , PATR No. 1372, 29 November 1943. (b) Also see the following Picatinny Arsenal Technical Reports on Ammonals: 1108, 1286, 1292, 1308 and 1783.

Composition: % N 35 H 5 O 60 C/H Ratio	Molecular Weight: ($H_4N_2O_3$) 80	
	Oxygen Balance: CO ₂ % +20 CO % +20	
	Density: gm/cc Crystal 1.73	
	Melting Point: °C 170	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 100+ Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 31 Sample Wt, mg 17	Boiling Point: °C	
	Refractive Index, n_{20}^D n_{25}^D n_{30}^D	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.3 120°C 0.3 135°C 150°C 0.3	
Rifle Bullet Impact Test: Trials Explosions % 0 Partial 0 0 Burned 0 Unaffected 100	200 Gram Bomb Sand Test: Sand, gm Nil	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Ignites 465 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.25	
75°C International Heat Test: (a) % Loss in 48 Hrs 0.0	Ballistic Mortar, % TNT: (a) 56	
	Trauzl Test, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs 0.74 % Loss, 2nd 48 Hrs 0.13 Explosion in 100 Hrs None	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
Flammability Index:	Detonation Rate: (b) Confinement None Strong Condition Solid Liquid Charge Diameter, in. 1.25 4.5 Density, gm/cc 0.9 1.4 Rate, meters/second 1000 2500	
Hygroscopicity: % 30°C, 90% RH Extreme		
Volatility: Decomposes at 210°C		

Booster Sensitivity Test: Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc	Decomposition Equation: (f) (h) Oxygen, atoms/sec 10 ^{13.8} 10 ^{12.3} (Z/sec) Heat, kilocalorie/mole 40.5 38.3 (ΔH, kcal/mol) Temperature Range, °C 243-261 217-267 Phase Liquid
Heat of: Combustion, cal/gm 346 Explosion, cal/gm 346 Gas Volume, cc/gm 980 Formation, cal/gm 1098 Fusion, cal/gm 18.23	Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bombs: Plate Thickness, inches 1 1¼ 1½ 1¾
Specific Heat: cal/gm/°C (e) °C °C -150 0.189 0 0.397 -100 0.330 50 0.414 -50 0.364 100 0.428	
Burning Rate: cm/sec	
Thermal Conductivity: cal/sec/cm/°C 2.9-3.9 x 10 ⁻⁴	
Coefficient of Expansion: Linear, %/°C Volume, %/°C	
Hardness, Mohs' Scale:	
Young's Modulus: E', dynes/cm ² E, lb/inch ² Density, gm/cc	
Compressive Strength: lb/inch ²	
Vapor Pressure: (g) °C mm Mercury 188 3.25 205 7.45 216 11.55 223 15.80 237 27.0 249 41.0	Bomb Drop Test: T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete: Max Safe Drop, ft 500-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order 1000-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order

<p>Fragmentation Test:</p> <p>90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments: For TNT For Subject HE</p> <p>3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments: For TNT For Subject HE</p> <p>Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc</p>	<p>Shaped Charge Effectiveness, TNT = 100:</p> <p>Glass Cones Steel Cones</p> <p>Hole Volume</p> <p>Hole Depth</p> <p>Color: Colorless</p> <p>Principal Uses: Explosive ingredient of mixtures used in bombs or large caliber projectiles</p> <p>Method of Loading: Pressed or cast depending on composition of mixture</p> <p>Loading Density: gm/cc Variable</p> <p>Storage:</p> <p>Method Dry</p> <p>Hazard Class (Quantity-Distance) Class 12</p> <p>Compatibility Group Group D</p> <p>Exudation None</p>												
<p>Blast (Relative to TNT):</p> <p>Air: Peak Pressure Impulse Energy</p> <p>Air, Confined: Impulse</p> <p>Under Water: Peak Pressure Impulse Energy</p> <p>Underground: Peak Pressure Impulse Energy</p>	<p>Effect of Temperature on Impact Sensitivity (Chemically pure grade): (b)</p> <table> <tr> <th>Temp. °C</th><th>PA Impact Test 2 Kg Wt, inches</th></tr> <tr> <td>25</td><td>31</td></tr> <tr> <td>75</td><td>28</td></tr> <tr> <td>100</td><td>27</td></tr> <tr> <td>150</td><td>27</td></tr> <tr> <td>175</td><td>12</td></tr> </table> <p><u>Compatibility with Metals:</u> (a)</p> <p>In the presence of moisture, ammonium nitrate reacts with copper, iron steel, brass, lead and cadmium.</p> <p><u>Entropy:</u> (g)</p> <p>cal/mol at 25°C 36.0</p>	Temp. °C	PA Impact Test 2 Kg Wt, inches	25	31	75	28	100	27	150	27	175	12
Temp. °C	PA Impact Test 2 Kg Wt, inches												
25	31												
75	28												
100	27												
150	27												
175	12												

Ammonium Nitrate

Solubility of ammonium nitrate, grams in 100 grams (%) of: (e)

<u>Water</u>		<u>Alcohol</u>		<u>Acetic Acid</u>		<u>Nitric Acid</u>		<u>Pyridine</u>
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>
0	118	20	2.5	16.6	0.0	0	45.1	25
20	192	40	5	27.0	0.39	15	73.0	~20-25
40	297	60	7.5	80.9	5.8	30	106	
60	421	78	10.5	101.0	20.7	75	201	
80	580			120.0	125			
100	871							

Preparation:

Ammonium nitrate is prepared by the neutralization of an aqueous solution of ammonia with nitric acid and evaporation of the solution. The product which is very pure is dried in a graining kettle.

Origin:

First prepared by Glauber in 1659 and first used as an explosive ingredient in 1867 when a Swedish patent was granted to Ohlsson and Norrbm for a composite dynamite.

Destruction by Chemical Decomposition:

Ammonium nitrate is decomposed by strong alkalis with the liberation of ammonia, and by sulfuric acid with the formation of ammonium sulfate and nitric acid.

References:³

(a) Departments of the Army and the Air Force TM 9-1910/TO 11a-1-34, Military Explosives, April 1955.

(b) P. F. Macy, T. D. Dudderar, E. F. Reese and L. H. Eriksen, Investigation of Sensitivity of Fertilizer Grade Ammonium Nitrate to Explosion, PATR No. 1658, 11 July 1947.

(c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(d) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(e) International Critical Tables, McGraw-Hill Book Co., N. Y., Land-Bornst.

G. D. Clift and B. T. Federoff, A Manual for Explosives Laboratories, Vol. II, Lefax Society, Inc., Philadelphia, 1943.

(f) R. J. Finkelstein and G. Gamow, Theory of the Detonation Process, NAVORD Report No. 90-46, 20 April 1947.

(g) George Feick, The Dissociation Pressure and Free Energy of Formation of Ammonium Nitrate, Arthur D. Little, Inc., J Am Chem Soc, 76, 5858-60 (1954).

(h) M. A. Cook and M. Taylor Abegg, "Isothermal Decomposition of Explosives," University of Utah, Ind Eng Chem, June 1956, pp. 1090 to 1095.

³See footnote 1, page 10.

(i) Also see the following Picatinny Arsenal Technical Reports on Ammonium Nitrate:

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
240	681	182	743	364	695	596	907	548	799
350	731	1302	1323	984	1145	666	1117	638	1369
630	1051	1682	1783	1094	1225	676	1947	938	1409
1290	1241		2183	1214	1455	946	2167	1008	
1720	1311			1234	1635	1106		1038	
	1391			1304	1675	1696			
	1431				1725				

Composition: % Cl 30.2 N 11.9 H 3.4 O 54.5 C/H Ratio Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 67 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 24 Sample Wt, mg 24 Friction Pendulum Test: Steel Shoe Snaps Fiber Shoe Unaffected Rifle Bullet Impact Test: Trials % Explosions Partial Burned Unaffected	NH_4ClO_4	Molecular Weight: (ClH_4NO_4) 117.5
		Oxygen Balance: CO ₂ % +27.3 CO % +27.3
		Density: gm/cc 1.95
		Melting Point: °C
		Freezing Point: °C
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 435 10 15 20 75°C International Heat Test: % Loss in 48 Hrs 100°C Heat Test: % Loss, 1st 48 Hrs 0.02 % Loss, 2nd 48 Hrs 0.00 Explosion in 100 Hrs None Flammability Index: Hygroscopicity: % Volatility:		Boiling Point: °C
		Refractive Index, n_{20}^D n_{25}^D n_{30}^D
		Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.13 120°C 0.20 135°C 150°C 0.32
		200 Gram Bomb Sand Test: Sand, gm 6.0
		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.25
		Ballistic Mortar, % TNT:
		Trauzl Test, % TNT:
		Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT
		Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Colorless Principal Uses: Explosive ingredient of mixtures used in pyrotechnics and as projectile filler Method of Loading: Pressed or cast depending on composition of mixture Loading Density: gm/cc Variable
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: <div style="display: flex; justify-content: space-around;"> Method Dry </div> <div style="display: flex; justify-content: space-around;"> Hazard Class (Quantity-Distance) Class 9 </div> <div style="display: flex; justify-content: space-around;"> Compatibility Group </div> <div style="display: flex; justify-content: space-around;"> Exudation None </div>
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	<div style="border: 1px solid black; padding: 5px;"> Solubility in Water <u>gm/100 cc saturated solution:</u> <div style="display: flex; justify-content: space-between;"> 0°C 12 </div> <div style="display: flex; justify-content: space-between;"> 25°C 20 </div> <div style="display: flex; justify-content: space-between;"> 60°C 39 </div> <div style="display: flex; justify-content: space-between;"> 100°C 88 </div> </div> Preparation: The perchlorates are prepared by the action of the acid on a suitable base; by the thermal decomposition of certain chlorates; and by the electrolysis of chlorates (see origin). Heat of: <div style="display: flex; justify-content: space-around;"> Formation, cal/gm 665 </div>

Origin: (c)

E. Mitscherlich first prepared, in 1832, crystals of ammonium perchlorate from barium perchlorate and ammonium sulfate (Pogg Ann 25, 300). T. Schlosing treated a hot solution of sodium perchlorate with ammonium chloride, and on cooling, crystals of ammonium perchlorate were obtained (Comp rend, 73, 1269, [1871]). U. Alvisi treated a mixture of 76 parts of ammonium nitrate with 213 parts of sodium perchlorate, and obtained a crop of small crystals of ammonium perchlorate which were purified by recrystallization from hot water (German Patent, 103,993, 1898). A. Miolati mixed magnesium or calcium perchlorate with ammonium chloride and crystals of ammonium perchlorate deposited from the solution of very soluble magnesium or calcium chloride (German Patent, 112, 682, 1899).

References:⁴

(a) W. R. Tomlinson, Jr., Physical and Explosive Properties of Military Explosives, PATR No. 1372, 29 November 1943.

(b) T. L. Davis, The Chemistry of Powder and Explosives, John Wiley and Sons, Inc., New York, 1943.

(c) J. W. Mellor, A Comprehensive Treatise on Inorganic and Theoretical Chemistry, Vol. II, Longmanns, Green and Co., London, 1922, p. 396.

(d) Also see the following Picatinny Arsenal Technical Reports on Ammonium Perchlorate:

<u>0</u>	<u>1</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>9</u>
100	321	843	354	1095	1726	1049
		1783	604	1725		1969
			854	2205		

⁴See footnote 1, page 10.

Baratol

AMCP 706-177

Composition: % Barium nitrate 67 TNT 33 C/H Ratio	Molecular Weight: 125	
	Oxygen Balance: CO ₂ % -3 CO % +13	
	Density: gm/cc	Cast 2.55
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 35 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 11 Sample Wt, mg 24	Boiling Point: °C	
	Refractive Index, n ₂₀ ^D n ₂₅ ^D n ₃₀ ^D	
	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C	
Friction Pendulum Test: Steel Shoe Fiber Shoe	200 Gram Bomb Sand Test: Sand, gm 26.8	
Rifle Bullet Impact Test: Trials % Explosions Partial Burned Unaffected	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.10	
	Ballistic Mortar, % TNT:	
	Trauzl Test, % TNT:	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Ignites 385 10 15 20	Plate Dent Test: (a) 73/27 Method B Condition Cast Confined No Density, gm/cc 2.52 Brisance, % TNT 61	
75°C International Heat Test: % Loss in 48 Hrs	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs		
Flammability Index:		
Hygroscopicity: % 30°C, 90% RH 0.00		
Volatility:		

Booster Sensitivity Test: Condition Cast Tetryl, gm 100 Wax, in. for 50% Detonation 0.32 Wax, gm Density, gm/cc 2.55	Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH, kcal/mol) Temperature Range, °C Phase																				
Heat of: Combustion, cal/gm Explosion, cal/gm Gas Volume, cc/gm Formation, cal/gm Fusion, cal/gm 75/25 Baratol 2.8 (d)	Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bombs: Plate Thickness, inches 1 1¼ 1½ 1¾																				
Specific Heat: cal/gm/°C (d) 75/25 Baratol <table><tr><td colspan="2">°C</td><td colspan="2">°C</td></tr><tr><td>-75</td><td>0.152</td><td>75</td><td>0.280</td></tr><tr><td>0</td><td>0.147</td><td>85</td><td>0.213</td></tr><tr><td>25</td><td>0.180</td><td>90</td><td>0.201</td></tr><tr><td>50</td><td>0.229</td><td>100</td><td>0.171</td></tr></table>	°C		°C		-75	0.152	75	0.280	0	0.147	85	0.213	25	0.180	90	0.201	50	0.229	100	0.171	Bomb Drop Test: T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete: Max Safe Drop, ft 500-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order 1000-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order
°C		°C																			
-75	0.152	75	0.280																		
0	0.147	85	0.213																		
25	0.180	90	0.201																		
50	0.229	100	0.171																		
Burning Rate: cm/sec																					
Thermal Conductivity: cal/sec/cm/°C																					
Coefficient of Expansion: Linear, %/°C Volume, %/°C																					
Hardness, Mohs' Scale:																					
Young's Modulus: E', dynes/cm² E, lb/inch² Density, gm/cc																					
Compressive Strength: lb/inch²																					
Vapor Pressure: °C mm Mercury																					

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Principal Uses: Bomb filler Method of Loading: Cast Loading Density: gm/cc 2.55
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: <div style="display: flex; justify-content: space-between;"> Method Dry </div> <div style="display: flex; justify-content: space-between;"> Hazard Class (Quantity-Distance) Class 9 </div> <div style="display: flex; justify-content: space-between;"> Compatibility Group Group I </div> Exudation
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Preparation: The appropriate weight of barium nitrate heated to about 90°C is added to molton TNT contained in a melting vessel equipped with an agitator. Continue mixing until uniform, and load by pouring at the lowest practical temperature. Origin: Baratol, an explosive containing barium nitrate and TNT, the proportions varied to suit the required purposes, was developed during World War I.

References:⁵

(a) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(b) L. C. Smith and E. G. Fyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(c) Also see the following Picatinny Arsenal Technical Reports on Baratol:

<u>0</u>	<u>3</u>	<u>6</u>	<u>8</u>
2010	1783	2226	2138
2160	2233		

(d) C. Lenchitz, W. Beach and R. Valicky, Enthalpy Changes, Heat of Fusion and Specific Heat of Basic Explosives, PATR No. 2504, January 1959.

⁵See footnote 1, page 10.

Composition: % Barium nitrate 50 TNT 35 Aluminum 15 C/H Ratio	Molecular Weight: 111	
	Oxygen Balance: CO ₂ % -24 CO % -7	
	Density: gm/cc 2.32	
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 30 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 12 Sample Wt, mg 22	Boiling Point: °C	
	Refractive Index, n_{20}^D n_{25}^D n_{30}^D	
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm 39.8	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Ignites 345 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.10	
	Ballistic Mortar, % TNT: (a) 96	
75°C International Heat Test: % Loss in 48 Hrs	Trauzl Test, % TNT:	
	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Detonation Rate: (b) Confinement None Condition Cast Charge Diameter, in. 1.0 Density, gm/cc 2.32 Rate, meters/second 5450	
Flammability Index:		
Hygroscopicity: %		
Volatility:		

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Principal Uses: Bomb filler Method of Loading: Cast Loading Density: gm/cc 232
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: <div style="display: flex; justify-content: space-between;"> Method Dry </div> <div style="display: flex; justify-content: space-between;"> Hazard Class (Quantity-Distance) Class 9 </div> <div style="display: flex; justify-content: space-between;"> Compatibility Group Group I </div> Exudation
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Preparation: Procedure same as described under <u>Baratol</u> except aluminum is added to the barium nitrate-TNT molton mixture under agitation until uniformity in comparison is obtained. Booster Sensitivity Test: <div style="display: flex; justify-content: space-between;"> <div> Condition Teteryl, gm Wax, in. for 50% Detonation Density, gm/cc </div> <div> (c) Cast 100 0.86 2.32 </div> </div> Heat of: <div style="display: flex; justify-content: space-between;"> <div> Combustion, cal/gm Explosion, cal/gm Gas Volume, cc/gm </div> <div> 2099 1135 410 </div> </div>

References:⁶

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) G. H. Messerly, The Rate of Detonation of Various Explosive Compounds, OSRD Report No. 1219, 22 February 1943.

M. D. Hurwitz, The Rate of Detonation of Various Compounds and Mixtures, OSRD Report No. 5611, 15 January 1946.

(c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(d) Arthur D. Little Report, Study of Pure Explosive Compounds, Part III, Correlation of Composition of Mixture with Performance, Contract No. DA-19-020-ORD-12, 1 May 1950.

(e) S. J. Lowell, Propagation of Detonation in Long and Narrow Columns of Explosives, PATR No. 2138, February 1955.

⁶See footnote 1, page 10.

Composition: % Potassium nitrate 74.0 Sulfur 10.4 Charcoal 15.6 C/H Ratio	Molecular Weight: 84		
	Oxygen Balance: CO ₂ % -22 CO % - 2		
	Density: gm/cc Variable		
	Melting Point: °C		
	Freezing Point: °C		
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 32 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 16 Sample Wt, mg 16	Boiling Point: °C		
	Refractive Index, n ₂₀ ^D n ₂₅ ^D n ₃₀ ^D		
Friction Pendulum Test: Steel Shoe Snaps Fiber Shoe Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.5 120°C 0.9 135°C 150°C		
	200 Gram Bomb Sand Test: Sand, gm 8		
Explosion Temperature: °C Seconds, 0.1 (no cap used) 510 1 490 5 Ignites 427 10 356 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl Sensitive to igniting fuse		
	Ballistic Mortar, % TNT: 50		
75°C International Heat Test: % Loss in 48 Hrs 0.31	Trauzl Test, % TNT: (a) 10		
	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT		
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc 1.6 Rate, meters/second 400		
	Flammability Index:		
Hygroscopicity: % 26°C, 75% RH 0.75 25°C, 90% RH 1.91 30°C, 90% RH 2.51			
	Volatility:		

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones Hole Volume Hole Depth
	Color: Black
	Principal Uses: 1. Igniter powder 2. Time rings (fuzes)
	Method of Loading: 1. Loose (granulated) 2. Pressed
	Loading Density: gm/cc psi x 10 ³ 25 50 60 65 70 75 1.74 1.84 1.86 1.87 1.88 1.89
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group 0 Exudation None
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	<u>100°C Vacuum Stability Test,</u> <u>cc gas/40 hrs:</u> Initial Value 0.5 After 2 hours at 65°C 0.86 After 2 hours at 65°C, 75% RH 1.46 <u>Sensitivity to Electrostatic</u> <u>Discharge, Joules:</u> (b) Unconfined >12.5 Confined 0.8 <u>Compatibility with Metals:</u> Dry - Compatible with all metals when moisture content is less than 0.20%. Wet - Attacks all common metals except stainless steel. <u>Heat of:</u> Explosion, cal/gm 684 Gas Volume, cc/gm 271
<u>Initiating Efficiency:</u> <u>Grams Required to Initiate</u> Igniter Comp K-31 2.0 Igniter Comp K-29 2.3	

Preparation:

Willow or alder charcoal, flour of sulphur and 2-3% of water are placed in a tumbling barrel and mixed for a short period (about 1/2 hour). The mixture is transferred to a "wheel mill" and crystalline potassium nitrate containing 3-4% moisture is added and the mixture is incorporated for several hours. During the incorporation period the mixture is kept damp (2-3% moisture) by adding water at intervals. The mill cake is then pressed at 6000 psi between aluminum plates. The pressed cakes are broken up between rubber or wood rolls. The material is screened and the various particle sizes are separated as desired. The screened material is then transferred to canvas trays and dried in hot air ovens at 60°C. If it is desired to glaze the black powder, the material before drying is polished by rotation in a tumbling barrel to give it a smooth surface. It is next screened to remove the dust. The smooth particles are then placed in a wooden barrel and rotated with graphite. The material is again screened to remove the excess graphite, and dried. Material finer than #40 U. S. Sieve is not graphited.

WARNING

The batches of black powder must be of sufficient size to cover the bed of the "wheel mill." If the wheels run off on the bare bed, explosions usually result.

Origin:

The exact date of the discovery of black powder is unknown. Historians attribute its discovery to the Chinese, Hindus or Arabs. The Greeks used it during the 7th Century. Marcus Graecus in the 9th Century and Roger Bacon in the 13th Century described compositions similar to the present powder. Beginning with the 16th Century, the composition of black powder containing potassium nitrate, charcoal and sulfur has remained unchanged with respect to the proportionality (75/15/10) of the ingredients.

Destruction by Chemical Decomposition:

Black powder can be desensitized by leaching with water to dissolve the potassium nitrate. The washings must be disposed of separately because the residue of sulfur and charcoal is combustible but not explosive.

References:⁷

- (a) Ph. Naoum, Nitroglycerine and Nitroglycerine Explosives, Baltimore, 1928.
- (b) F. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Department of the Interior, Bureau of Mines RI 3852, 1946.
- (c) Also see the following Picatinny Arsenal Technical Reports on Black Powder:

⁷See footnote 1, page 10.

Black Powder

AMCP 706-177

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
250	91	222	163	354	65	56	347	188	379
710	471	272	363	454	415	176	407	318	819
850	661	322	453	544	545	356	437	428	839
1010	901	472	843	554	605	686	547	558	849
1450	1111	492	1043	574	1145	746	757	598	859
	1241	582	1153	594	1275	1256	847	608	899
	1451	762	1243	654	1815	1316	1097	618	1259
	1541	872	1333	664	1885	1536	1737	698	1309
	1711	1022	1493	774	1905	1576	1797	838	1339
	1911	1622	1583	844	1915	1586	1807	898	1349
	1951	1712	1643	1114		1946	1827	1068	1589
	2051	1802	1813	1154				1388	1739
		1912	1843	1244				1528	1869
			1973	1504				1778	1889
								1808	
								1838	
								1928	
								2178	

Composition: % C 19.9 H 2.9 N 17.5 O 59.7 C/H Ratio 0.13 $\begin{array}{c} \text{H}_2\text{C}-\text{ONO}_2 \\ \\ \text{H}_2\text{C} \\ \\ \text{HC}-\text{ONO}_2 \\ \\ \text{H}_2\text{C}-\text{ONO}_2 \end{array}$	Molecular Weight: (C ₄ H ₇ N ₃ O ₉) 241	
	Oxygen Balance: CO ₂ % -17 CO % 10	
	Density: gm/cc	Liquid 1.52
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 58 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. ≤ 1 Sample Wt, mg	Boiling Point: °C	
	Refractive Index, n _D ²⁰ 1.4738 n _D ²⁵ n _D ³⁰	
	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 2.33 120°C 135°C 150°C	
Friction Pendulum Test: Steel Shoe Fiber Shoe	200 Gram Bomb Sand Test: Sand, gm 48.6	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.10	
	Ballistic Mortar, % TNT:	
	Trauzl Test, % TNT:	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 230 10 15 20	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
75°C International Heat Test: % Loss in 48 Hrs	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
100°C Heat Test: % Loss, 1st 48 Hrs 1.5 % Loss, 2nd 48 Hrs 1.2 Explosion in 100 Hrs None		
Flammability Index:		
Hygroscopicity: % (a) 100°F, 95% RH, 24 hrs 0.14		
Volatility: 60°C, mg/cm ² /hr 46		

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones Hole Volume Hole Depth Color: Yellow oil Principal Uses: Explosive plasticizer for nitrocellulose Method of Loading: Loading Density: gm/cc 1.52
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Hazard Class (Quantity-Distance) Compatibility Group Exudation
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy <u>Heat of:</u> (a) Combustion, cal/gm 2168 Explosion, cal/gm 1457 Gas Volume, cc/gm 840	Solubility in Water, (a) <u>gm/100 gm, at:</u> 20°C 0.08 60°C 0.15 Solubility of Water in, (a) <u>gm/100 gm:</u> 0.04 Solubility, gm/100 gm, <u>at 25°C, in:</u> Ether ∞ Alcohol ∞ 2:1 Ether:Alcohol ∞ Acetone ∞ <u>Viscosity, centipoises:</u> (a) Temp, 25°C 59

Preparation (Laboratory Procedure):

To a cooled mixture of 73.8 gm of 100% nitric acid, 46.2 gms of 106.2% sulfuric acid and 60.0 gm of 96.1% sulfuric acid, 30 gms of the original (or redistilled) 1,2,4-butanetriol was added dropwise with agitation for a period of thirty minutes. The temperature of the reaction mixture was kept at 0°-5°C. When the agitation was completed, stirring was continued for one and one-half hours. The mixture was poured into ice water, and the resulting oil suspension was extracted with three 100 milliliter portions of ether. The combined ether extracts were washed with water, then with a 5% sodium bicarbonate solution and finally with water. The neutralized extract was dried with anhydrous calcium chloride and then the ether was evaporated. The yellow oil was dried in a vacuum desiccator over anhydrous calcium chloride until the material was brought to constant weight.

Origin:

1,2,4-butanetriol was first synthesized by Wagner and Ginsberg in 1894 by oxidizing allyl carbinol with potassium permanganate under mild conditions (Ber 27, 2437). Recently the U. S. Rubber Laboratory, under the direction of P. Tawney, devised a new synthesis carried out with allyl acetate and formaldehyde to give 1,2,4-butane triacetate which was readily hydrolysed to butanetriol (U. S. Rubber Company Quarterly Report, May 1948). Working with pure 1,2,4-butanetriol prepared by an improved technique of the Wagner method, the U. S. Naval Laboratory in 1948 nitrated the butanetriol on a laboratory and a pilot plant scale (Reference a).

References:⁸

(a) J. A. Gallagher, F. Macri, J. Bednarik, and F. McCollum, The Synthesis of 1,2,4-Butanetriol and the Evaluation of Its Trinitrate, U. S. Naval Powder Factory Technical Report No. 19, 10 September 1948.

(b) Also see the following Picatinny Arsenal Technical Reports on Butanetriol Trinitrate: 1755 and 1786.

⁸See footnote 1, page 10.

Composition A-3

AMCP 706-177

Composition: % RDX 91 Wax 9 C/H Ratio	Molecular Weight: 227	
	Oxygen Balance: CO ₂ % -48 CO % -23	
	Density: gm/cc 12,000 psi 1.65	
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 100+ Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 16 Sample Wt, mg 17	Boiling Point: °C	
	Refractive Index, n_D^{20} n_D^{25} n_D^{30}	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.3 120°C 0.6 135°C 150°C	
Rifle Bullet Impact Test: Trials % Explosions 0 Partial 0 Burned 0 Unaffected 100	200 Gram Bomb Sand Test: Sand, gm 51.5	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 250 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.22* Lead Azide 0.25* * Tetryl * Alternative initiating charges	
75°C International Heat Test: % Loss in 48 Hrs	Ballistic Mortar, % TNT: (a) 135	
	Trauzl Test, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs 0.15 % Loss, 2nd 48 Hrs 0.15 Explosion in 100 Hrs None	Plate Dent Test: (b) Method B B Condition Pressed Pressed Confined No No Density, gm/cc 1.61 1.20 Brisance, % TNT 126 75	
Flammability Index: 195	Detonation Rate: (c) Confinement None Condition Pressed Charge Diameter, in. 1.0 Density, gm/cc 1.59 Rate, meters/second 8100	
Hygroscopicity: % 30°C, 90% RH 0.0		
Volatility: 50°C, 15 days 0.03		

<p>Fragmentation Test:</p> <p>90 mm HE, M71 Projectile, Lot WC-91:</p> <p>Density, gm/cc 1.62</p> <p>Charge Wt, lb 2.102</p> <p>Total No. of Fragments:</p> <p>For TNT 703</p> <p>For Subject HE 1138</p> <p>3 inch HE, M42A1 Projectile, Lot KC-5:</p> <p>Density, gm/cc 1.64</p> <p>Charge Wt, lb 0.861</p> <p>Total No. of Fragments:</p> <p>For TNT 514</p> <p>For Subject HE 710</p> <p>Fragment Velocity: ft/sec</p> <p>At 9 ft 2800</p> <p>At 25½ ft 2530</p> <p>Density, gm/cc 1.61</p>	<p>Shaped Charge Effectiveness, TNT = 100:</p> <p>Glass Cones Steel Cones</p> <p>Hole Volume</p> <p>Hole Depth</p> <p>Color: White-buff</p> <p>Principal Uses: HE, SAP, AP projectiles; Shaped Charges</p> <p>Method of Loading: Pressed</p> <p>Loading Density: gm/cc psi x 10³</p> <p>3 12</p> <p>1.47 1.65</p> <p>Storage:</p> <p>Method Dry</p> <p>Hazard Class (Quantity-Distance) Class 9</p> <p>Compatibility Group Group I</p> <p>Exudation Does not exude at 65°C when waxes melting sharply at or above 75°C are used.</p>
<p>Blast (Relative to TNT):</p> <p>Air:</p> <p>Peak Pressure</p> <p>Impulse</p> <p>Energy</p> <p>Air, Confined:</p> <p>Impulse</p> <p>Under Water:</p> <p>Peak Pressure</p> <p>Impulse</p> <p>Energy</p> <p>Underground:</p> <p>Peak Pressure</p> <p>Impulse</p> <p>Energy</p>	<p>Preparation:</p> <p>A water slurry of RDX is heated to 100°C with agitation. Wax and a wetting agent are added and the mixture, under agitation, is cooled below the melting point of the wax. The wax coated RDX is collected on a filter and air dried at 75°C.</p> <p>Effect of Temperature on</p> <p>Rate of Detonation: (e)</p> <p>16 hrs at, °C -54 21</p> <p>Density, gm/cc 1.51 1.51</p> <p>Rate, m/sec 7600 7620</p> <p>Booster Sensitivity Test: (d)</p> <p>Condition Pressed</p> <p>Tetryl, gm 100</p> <p>Wax, in. for 50% Detonation 1.70</p> <p>Density, gm/cc 1.62</p> <p>Heat of:</p> <p>Combustion, cal/gm 1210</p>

Compatibility with Metals:

Dry - Aluminum, stainless steel, mild steel, mild steel coated with acid-proof black paint and mild steel plated with nickel or zinc are unaffected. Copper, magnesium, magnesium-aluminum alloy, brass and mild steel plated with cadmium or copper are slightly affected.

Wet - Stainless steel is unaffected. Copper, aluminum, magnesium, brass, mild steel, mild steel coated with acid-proof black paint and mild steel plated with copper, cadmium, nickel or zinc are slightly affected.

Origin:

Developed by the British during World War II as RDX and beeswax. Subsequent changes in the United States replaced beeswax with synthetic waxes, changed the granulation of RDX and improved the method of manufacture.

Destruction by Chemical Decomposition:

RDX Composition A-3 (RDX/wax, 91/9) is decomposed by adding it slowly to 25 times its weight of boiling 5% sodium hydroxide. Boiling of the solution is continued for one-half hour.

References:⁹

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(c) G. H. Messerly, The Rate of Detonation of Various Explosive Compounds, OSRD Report No. 1219, 22 February 1943.

M. D. Hurwitz, The Rate of Detonation of Various Compounds and Mixtures, OSRD Report No. 5611, 15 January 1946.

(d) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Teteryl in Boosters, NOL Memo 10,303, dated 15 June 1949.

(e) W. F. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Different Temperatures, PATR No. 2383, November 1956.

(f) Also see the following Picatinny Arsenal Technical Reports on RDX Composition A-3:

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
1380	1451	1492	1493	1424	1325	1556	1687	1338	1639
1910	1761	2112		1614	1585	1936	1787	1388	2179
				1634	1595		1797	1728	
				2154	1715			1838	
					1885				
					2235				

⁹See footnote 1, page 10.

Composition: % RDX 60 TNT 40 Wax, added 1 C/H Ratio	Molecular Weight: 224	
	Oxygen Balance: CO ₂ % -43 CO % 10	
	Density: gm/cc	Cast 1.65
	Melting Point: °C	(1) 78-80
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 75 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 14 Sample Wt, mg 19	Boiling Point: °C	
	Refractive Index, n_{20}^D n_{25}^D n_{30}^D	
	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.7 120°C 0.9 135°C 150°C 11+	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	200 Gram Bomb Sand Test: Sand, gm 54.0	
Rifle Bullet Impact Test: Trials Explosions % 3 Partial 13 Burned 4 Unaffected 80	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.22* Lead Azide 0.20* Tetryl * Alternative initiating charges	
	Ballistic Mortar, % TNT: (a)	133
Explosion Temperature: °C Seconds, 0.1 (no cap used) 526 1 368 5 Decomposes 278 10 255 15 > 250 20 > 250	Trauzl Test, % TNT: (b)	130
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: (c)	Method B Condition Cast Confined No Density, gm/cc 1.71 Brisance, % TNT 132
100°C Heat Test: % Loss, 1st 48 Hrs 0.2 % Loss, 2nd 48 Hrs 0.2 Explosion in 100 Hrs None	Detonation Rate: Confinement None Condition Cast Charge Diameter, in. 1.0 Density, gm/cc 1.68 Rate, meters/second 7840	
Flammability Index: 177		
Hygroscopicity: % 30°C, 90% RH 0.02		
Volatility:		

Booster Sensitivity Test: Condition Tetryl, gm Wax, in. for 50 % Detonation Wax, gm Density, gm/cc	(d) Cast 100 1.40 1.69
Heat of: Combustion, cal/gm Explosion, cal/gm Gas Volume, cc/gm Formation, cal/gm Fusion, cal/gm	(e) 2790 1240 (1) 8.0
Specific Heat: cal/gm/°C °C	(1) °C -75 0.235 75 0.376 0 0.220 85 0.354 25 0.254 90 0.341 50 0.305 100 0.312
Burning Rate: cm/sec	
Thermal Conductivity: cal/sec/cm/°C	
Coefficient of Expansion: Linear, %/°C Volume, %/°C	
Hardness, Mohs' Scale:	
Young's Modulus: E', dynes/cm² E, lb/inch² Density, gm/cc	
Compressive Strength: lb/inch² (b) Density, gm/cc	1610-2580 1.68
Vapor Pressure: °C	mm Mercury

Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH, kcal/mol) Temperature Range, °C Phase																		
Armor Plate Impact Test: 60 mm Mortar Projectile: 50 % Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bombs: Plate Thickness, inches <table><tr><td></td><td><u>Trials</u></td><td><u>% Inert</u></td></tr><tr><td>1</td><td>4</td><td>100</td></tr><tr><td>1¼</td><td>6</td><td>50</td></tr><tr><td>1½</td><td>2</td><td>0</td></tr><tr><td>1¾</td><td>0</td><td></td></tr></table>		<u>Trials</u>	<u>% Inert</u>	1	4	100	1¼	6	50	1½	2	0	1¾	0				
	<u>Trials</u>	<u>% Inert</u>																
1	4	100																
1¼	6	50																
1½	2	0																
1¾	0																	
Bomb Drop Test: T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete: Max Safe Drop, ft 500-lb General Purpose Bomb vs Concrete: <table><tr><td></td><td><u>No Seal</u></td><td><u>Seal</u></td></tr><tr><td>Height, ft</td><td>4000</td><td>4000</td></tr><tr><td>Trials</td><td>65</td><td>39</td></tr><tr><td>Unaffected</td><td>58</td><td>36</td></tr><tr><td>Low Order</td><td>2</td><td>2</td></tr><tr><td>High Order</td><td>5</td><td>1</td></tr></table> 1000-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order		<u>No Seal</u>	<u>Seal</u>	Height, ft	4000	4000	Trials	65	39	Unaffected	58	36	Low Order	2	2	High Order	5	1
	<u>No Seal</u>	<u>Seal</u>																
Height, ft	4000	4000																
Trials	65	39																
Unaffected	58	36																
Low Order	2	2																
High Order	5	1																

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc 1.65 Charge Wt, lb 2.187 Total No. of Fragments: For TNT 703 For Subject HE 998 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc 1.67 Charge Wt, lb 0.882 Total No. of Fragments: For TNT 514 For Subject HE 701	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> <div>(g)</div> <div>(h)</div> </div> <div style="display: flex; justify-content: space-around;"> <div>Glass Cones</div> <div>Steel Cones</div> </div> Hole Volume 178 162 Hole Depth 125 148
Fragment Velocity: ft/sec At 9 ft 2940 At 25½ ft 2680 Density, gm/cc 1.68	Color: Yellow-brown
Blast (Relative to TNT): (f) Air: Peak Pressure 110 Impulse 110 Energy 116 Air, Confined: Impulse 75 Under Water: Peak Pressure 110 Impulse 108 Energy 121 Underground: Peak Pressure 104 Impulse 97 Energy Crater radius cubed 107	Principal Uses: Fragmentation bombs, HE projectiles, grenades, shaped charges
	Method of Loading: Cast
	Loading Density: gm/cc 1.68
	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation Very slight when stored at 71°C
	Origin: RDX Composition B was developed by the British between World War I and World War II. It was standardized by the United States early in World War II. Effect of Temperature on <u>Rate of Detonation:</u> (i) <div style="display: flex; justify-content: space-around;"> <div>16 hrs at, °C</div> <div>-54</div> <div>24</div> </div> <div style="display: flex; justify-content: space-around;"> <div>Density, gm/cc</div> <div>1.69</div> <div>1.69</div> </div> <div style="display: flex; justify-content: space-around;"> <div>Rate, m/sec</div> <div>7720</div> <div>7660</div> </div> Bulk Modulus at Room (j) <u>Temperature (25°-30°C):</u> <div style="display: flex; justify-content: space-around;"> <div>% Wax in Comp B</div> <div>1</div> <div>2</div> <div>3</div> </div> <div style="display: flex; justify-content: space-around;"> <div>Dynes/cm² x 10⁻¹⁰</div> <div>5.10</div> <div>3.56</div> <div>2.34</div> </div> <div style="display: flex; justify-content: space-around;"> <div>Density, gm/cc</div> <div>1.72</div> <div>1.70</div> <div>1.68</div> </div> <u>Viscosity, poises:</u> <div style="display: flex; justify-content: space-around;"> <div>Temp, 83°C</div> <div></div> <div>3.1</div> </div> <div style="display: flex; justify-content: space-around;"> <div>95°C</div> <div></div> <div>2.7</div> </div>

Composition BCompatibility with Metals:

Dry - Magnesium, aluminum, magnesium-aluminum alloy, mild steel, stainless steel, mild steel coated with acid-proof black paint and mild steel plated with zinc or nickel are unaffected. Copper, brass and mild steel plated with copper or cadmium are slightly affected.

Wet - Aluminum and stainless steel are unaffected. Copper, brass, mild steel, mild steel coated with acid-proof black paint and mild steel plated with cadmium, copper, nickel or zinc are slightly affected. Magnesium and magnesium-aluminum alloy are more heavily affected.

Preparation:

Water wet RDX is added slowly with stirring to molten TNT melted in a steam-jacketed kettle at a temperature of 100°C. Some water is poured off and heating and stirring are continued until all moisture is evaporated. Wax is then added and when thoroughly mixed, the composition is cooled to a satisfactory pouring temperature. It is cast directly into ammunition components or in the form of chips when Composition B is to be stored.

Destruction by Chemical Decomposition:

RDX Composition B is decomposed in 12 parts by weight of technical grade acetone heated to 45°C. While this is stirred vigorously, there is added 12 parts of a solution, heated to 70°C, of 1 part sodium sulfide ($\text{Na}_2\text{S} \cdot 9\text{H}_2\text{O}$) in 4 parts water. The sulfide solution is added slowly so that the temperature of the acetone solution does not rise above 60°C. After addition is complete, stirring is continued for one-half hour.

References:¹⁰

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.
- (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (d) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Teteryl in Boosters, NOL Memo 10,303, 15 June 1949.
- (e) Committee of Divisions 2 and 8, NDRC, Report on HBX and Tritonal, OSRD Report No. 5406, 31 July 1945.
- (f) W. R. Tomlinson, Jr., Blast Effects of Bomb Explosives, PA Tech Div Lecture, 9 April 1948.
- (g) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Sec III, Variation of Cavity Effect with Explosive Composition, NDRC Contract W672-ORD-5723.
- (h) Eastern Laboratory du Pont, Investigation of Cavity Effect, Final Report, E Lab du Pont, Contract W-672-ORD-5723, 18 September 1943.
- (i) W. F. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Different Temperatures, PATR No. 2383, November, 1956.

¹⁰See footnote 1, page 10.

(j) W. S. Cramer, Bulk Compressibility Data on Several High Explosives, NAVORD Report No. 4380, 15 September 1956.

(k) Also see the following Picatinny Arsenal Technical Reports on RDX Composition B:

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
1360	1211	1402	1313	1224	1325	1466	1207	1338	1339
1530	1451	1482	1433	1424	1435	1476	1437	1388	1379
2100	2131	1592	1803	1944	1585	1556	1457	1438	1469
2160	2151		1983	2004	1595	1756	1737	1458	1819
2190			2053	2104	1865	1956	1797	1688	2019
			2063		1885	2236	2007	1728	
			2103		2055		2147	1828	
			2233		2125			1838	
					2155			1978	
					2175			2008	
					2235			2138	
								2168	

(l) C. Lenchitz, W. Beach and R. Valicky, Enthalpy Changes, Heat of Fusion and Specific Heat of Basic Explosives, PATR No. 2504, January 1959.

**Desensitized Comp B, designated II, uses coated RDX.

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones Hole Volume Hole Depth Color: Yellow-brown Principal Uses: Bombs Method of Loading: Cast Loading Density: gm/cc 1.65 Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation Viscosity, poises: <u>I*</u> <u>II**</u> Temp, 83°C 3.5 3.1 95°C 2.6 2.7 References: (a) See the following Picatinny Arsenal Technical Reports on RDX Composition B, Desensitized: 1 3 5 6 2151 1313 1435 1756 2053 1865
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*Desensitized Comp B, designated I, uses emulsified wax.

**Desensitized Comp B, designated II, uses coated RDX.

Composition: % RDX 88.3 Plasticizer, non-explosive 11.7* *Nonexplosive oily plasticizer containing 0.6% lecithin. C/H Ratio	Molecular Weight:	
	Oxygen Balance: CO ₂ % CO %	
	Density: gm/cc	
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 100+ Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	Boiling Point: °C	
	Refractive Index, n ₂₀ ^D n ₂₅ ^D n ₃₀ ^D	
	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.3 120°C 0.7 135°C 150°C	
Friction Pendulum Test: Steel Shoe Fiber Shoe	200 Gram Bomb Sand Test: Sand, gm 46.5	
Rifle Bullet Impact Test: Trials % Explosions 0 Partials 0 Burned 0 Unaffected 100	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.25 Tetryl 0.11	
	Ballistic Mortar, % TNT: (a) 120	
	Trauzl Test, % TNT:	
	Plate Dent Test: Method A Condition Hand Tamped Confined Yes Density, gm/cc 1.58 Brisance, % TNT 112	
	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 285 10 15 20	75°C International Heat Test: % Loss in 48 Hrs	
100°C Heat Test: % Loss, 1st 48 Hrs 0.04 % Loss, 2nd 48 Hrs 0.00 Explosion in 100 Hrs None	Flammability Index:	
Hygroscopicity: % 30°C, 95% RH 0.25	Volatility: 25°C, 5 days 0.00	

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <table><tr><td></td><td>(f)</td><td>(g)</td></tr><tr><td></td><td>Glass Cones</td><td>Steel Cones</td></tr><tr><td>Hole Volume</td><td>113</td><td>114</td></tr><tr><td>Hole Depth</td><td>101</td><td>114</td></tr></table> Color: White Principal Uses: Plastic demolition explosive Method of Loading: Hand tamped Loading Density: gm/cc 1.49 Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation Exudes above 40°C <u>Plasticity:</u> <table><tr><td>Below 0°C</td><td>Brittle (0°C)</td></tr><tr><td>0-40°C</td><td>Plastic</td></tr><tr><td>Above 40°C</td><td>Exudes (40°C)</td></tr></table> <u>References:</u> See references for Composition C-4.		(f)	(g)		Glass Cones	Steel Cones	Hole Volume	113	114	Hole Depth	101	114	Below 0°C	Brittle (0°C)	0-40°C	Plastic	Above 40°C	Exudes (40°C)
	(f)	(g)																	
	Glass Cones	Steel Cones																	
Hole Volume	113	114																	
Hole Depth	101	114																	
Below 0°C	Brittle (0°C)																		
0-40°C	Plastic																		
Above 40°C	Exudes (40°C)																		
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc																			
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy																			

Composition: % RDX 78.7 TNT 5.0 DNT 12.0 MNT 2.7 NC 0.6 Solvent 1.0 C/H Ratio	Molecular Weight:	
	Oxygen Balance: CO ₂ % CO %	
	Density: gm/cc	
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 90 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	Boiling Point: °C	
	Refractive Index, n_{20}^D n_{25}^D n_{30}^D	
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 2.0 120°C 9.0 135°C 150°C	
Rifle Bullet Impact Test: Trials Explosions % 0 Partial 20 Burned 0 Unaffected 80	200 Gram Bomb Sand Test: Sand, gm 47.5	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 285 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.25 Tetryl 0.10	
75°C International Heat Test: % Loss in 48 Hrs	Ballistic Mortar, % TNT: (a) 126	
	Trauzl Test, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs 1.8 % Loss, 2nd 48 Hrs 1.4 Explosion in 100 Hrs None	Plate Dent Test: (c) Method B Condition Hand tamped Confined No Density, gm/cc 1.52 Brisance, % TNT 111	
Flammability Index: 178	Detonation Rate: (d) Confinement None Condition Hand tamped Charge Diameter, in. 1.0 Density, gm/cc 1.57 Rate, meters/second 7660	
Hygroscopicity: % 30°C, 95% RH 0.55		
Volatility: 25°C, 5 days 0.00		

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: White Principal Uses: Plastic demolition explosive Method of Loading: Hand tamped Loading Density: gm/cc 1.57
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Storage: <div style="display: flex; justify-content: space-around;"> Method Dry </div> <div style="display: flex; justify-content: space-around;"> Hazard Class (Quantity-Distance) Class 9 </div> <div style="display: flex; justify-content: space-around;"> Compatibility Group Group I </div> <div style="display: flex; justify-content: space-around;"> Exudation Volatilizes above 52°C </div> Plasticity: <div style="display: flex; justify-content: space-around;"> <div> Below 0°C 0-40°C above 40°C </div> <div> Plastic (-30°C) Plastic Hard (52°C)* </div> </div> <p>*Due to volitalization of plasticizer.</p> References: See references for Composition C-4.

Composition:		Molecular Weight:	
%		Oxygen Balance:	
RDX	77	CO ₂ %	
Tetryl	3	CO %	
TNT	4	Density: gm/cc	
DNT	10	Melting Point: °C	
MNT	5	Freezing Point: °C	
NC	1	Boiling Point: °C	
C/H Ratio		Refractive Index, n_{20}^D	
Impact Sensitivity, 2 Kg Wt:		n_{25}^D	
Bureau of Mines Apparatus, cm	100+	n_{30}^D	
Sample Wt 20 mg		Vacuum Stability Test:	
Picatinny Arsenal Apparatus, in.	14	cc/40 Hrs, at	
Sample Wt, mg	33	90°C	
Friction Pendulum Test:		100°C	1.21
Steel Shoe	Unaffected	120°C	11+
Fiber Shoe	Unaffected	135°C	
Rifle Bullet Impact Test:		150°C	
	Trial	200 Gram Bomb Sand Test:	
	%	Sand, gm	53.1
Explosions	0	Sensitivity to Initiation:	
Partials	40	Minimum Detonating Charge, gm	
Burned	0	Mercury Fulminate	
Unaffected	60	Lead Azide	0.20
Explosion Temperature: °C		Tetryl	0.08
Seconds, 0.1 (no cap used)		Ballistic Mortar, % TNT: (a)	126
1		Trauzl Test, % TNT: (b)	117
5	Decomposes 280	Plate Dent Test: (c)	
10		Method	B
15		Condition	Hand tamped
20		Confined	No
75°C International Heat Test:		Density, gm/cc	1.57
% Loss in 48 Hrs		Brisance, % TNT	118
100°C Heat Test:		Detonation Rate: (d)	
% Loss, 1st 48 Hrs	3.20	Confinement	None
% Loss, 2nd 48 Hrs	1.63	Condition	Hand tamped
Explosion in 100 Hrs	None	Charge Diameter, in.	1.0
Flammability Index:		Density, gm/cc	1.60
Hygroscopicity: % 30°C, 95% RH		Rate, meters/second	7625
Volatility: 25°C, 5 days			

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc 158 Charge Wt, lb 2045 Total No. of Fragments: For TNT 703 For Subject HE 944 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc 1.60 Charge Wt, lb 0.842 Total No. of Fragments: For TNT 514 For Subject HE 671	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones Hole Volume Hole Depth Color: Yellow Principal Uses: Plastic demolition explosive Method of Loading: Hand tamped Loading Density: gm/cc 1.58
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation Exudes at 77°C
Blast (Relative to TNT): Air: Peak Pressure 105 Impulse 109 Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Plasticity: Below 0°C Hard (-29°C) 0-40°C Plastic Above 40°C Exudes (77°C) Booster Sensitivity Test: (h) Condition Pressed Tetryl, gm 100 Wax, in. for 50% Detonation 1.36 Density, gm/cc 1.62 References: See references for Composition C-4.

Composition: % RDX 91 Plasticizer, non-explosive 9* * Contains polyisobutylene 2.1%; motor oil 1.6% and di(2-ethylhexyl) sebacate 5.3%. C/H Ratio	Molecular Weight:	
	Oxygen Balance: CO ₂ % CO %	
	Density: gm/cc	
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 100+ Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 19 Sample Wt, mg 27	Boiling Point: °C	
	Refractive Index, n_{20}^D n_{25}^D n_{30}^D	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.26 120°C 135°C 150°C	
Rifle Bullet Impact Test: Trials Explosions % 0 Partial 0 Burned 20 Unaffected 80	200 Gram Bomb Sand Test: Sand, gm 55.7	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 290 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.10	
	Ballistic Mortar, % TNT: (a) 130	
75°C International Heat Test: % Loss in 48 Hrs	Trauzl Test, % TNT:	
	Plate Dent Test: (c) Method B Condition Hand tamped Confined No Density, gm/cc 1.60 Brisance, % TNT 115	
100°C Heat Test: % Loss, 1st 48 Hrs 0.13 % Loss, 2nd 48 Hrs 0.00 Explosion in 100 Hrs None	Detonation Rate: (d) Confinement None Condition Hand tamped Charge Diameter, in. 1.0 Density, gm/cc 1.59 Rate, meters/second 8040	
Flammability Index:		
Hygroscopicity: % 30°C, 95% RH Nil		
Volatility:		

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Light brown Principal Uses: Plastic demolition explosive Method of Loading: Hand tamped Loading Density: gm/cc 1.60
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation None at 77°C
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	<div> Effect of Temperature on (i) Rate of Detonation: </div> <div> 16 hrs at, °C -54 21 Density, gm/cc 1.36 1.35 Rate, m/sec 7020 7040 </div> Plasticity: Below 0°C Plastic (-57°C) 0-40°C Plastic Above 40°C Plastic (77°C)

Preparation:

In manufacturing Composition C-3, the mixed plasticizing agent is heated in a melting kettle at 100°C. Water-wet RDX is added and heating and stirring are continued until all the water is evaporated. This mixture is then cooled and hand pressed into demolition blocks or special item ammunition.

Composition C-4 is prepared by hand kneading and rolling, or in a Schrader Bowl mixer, RDX of 44 micron size or less with the polyisobutylene-plasticizer previously made up in ether. The thoroughly blended explosive is dried in air at 60°C and loosely packed by hand tamping to its maximum density.

Origin:

Developed by the British during World War II as a plastic explosive which could be hand shaped. It was standardized in the United States during World War II and subsequent development led to mixtures designated C-2, C-3 and C-4.

Destruction by Chemical Decomposition:

Composition C-3 is decomposed by adding it slowly to a solution composed of 1 1/4 parts sodium hydroxide, 11 parts water, and 4 parts 95% alcohol, heated to 50°C. After addition of Composition C-3 is complete, the solution is heated to 80°C and maintained at this temperature for 15 minutes.

References:¹¹

- (a) Committee of Div 2 and 8, NDRC, Report on HBX and Tritonal, OSRD No. 5406, 31 July 1945.
- (b) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.
- (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (d) G. H. Messerly, The Rate of Detonation of Various Explosive Compounds, OSRD Report No. 1219, 22 February 1943.
- M. D. Hurwitz, The Rate of Detonation of Various Compounds and Mixtures, OSRD Report No. 5611, 15 January 1946.
- (e) W. R. Tomlinson, Jr., Blast Effects of Bomb Explosives, PA Tech Div Lecture, 9 April 1948.
- (f) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Sec III, Variation of Cavity Effect with Explosive Composition, NDRC Contract W672-ORD-5723.
- (g) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Final Report, 18 September 1943, NDRC Contract W-672-ORD-5723.
- (h) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Teteryl in Boosters, NOL Memo 10,303, 15 June 1949.

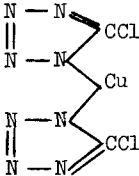
¹¹See footnote 1, page 10.

Compositions C, C-2, C-3, C-4

(i) W. F. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Temperatures, PATR No. 2383, November 1956.

(j) Also see the following Picatinny Arsenal Technical Reports on RDX Composition C:

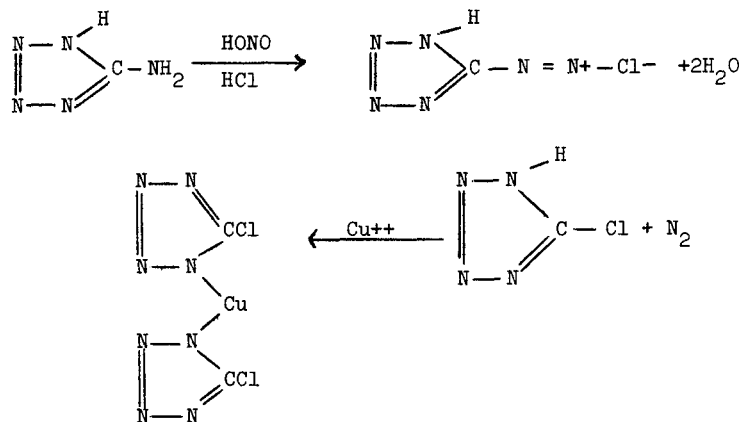
	<u>0</u>	<u>1</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
<u>Comp C</u>	1260		1293					1518 1838	
<u>Comp C-2</u>			1293			1416		1518	
<u>Comp C-3</u>		1611	1713	2154	1595 1695 1885	1416 1556 1766	1797	1518 2028	
<u>Comp C-4</u>						1766	1907	1828 1958	1819

Composition:			Molecular Weight: (CuC ₂ N ₈ Cl ₂) 271		
%					
C	8.9				
N	41.5				
Cl	26.2				
Cu	23.4				
C/H Ratio					
Impact Sensitivity, 2 Kg Wt:					
Bureau of Mines Apparatus, cm					
Sample Wt 20 mg					
Picatinny Arsenal Apparatus, in. 1; (1 lb wt) 3					
Sample Wt, mg 9					
Friction Pendulum Test:					
Steel Shoe Exploded					
Fiber Shoe Exploded					
Rifle Bullet Impact Test: Trials					
%					
Explosions					
Partials					
Burned					
Unaffected					
Explosion Temperature: °C					
Seconds, 0.1 (no cap used)					
1					
5 305					
10					
15					
20					
75°C International Heat Test:					
% Loss in 48 Hrs					
100°C Heat Test:					
% Loss, 1st 48 Hrs 2.67					
% Loss, 2nd 48 Hrs 0.10					
Explosion in 100 Hrs None					
Flammability Index:					
Hygroscopicity: % 30°C, 90% RH 3.11					
Volatility:					
Oxygen Balance:					
CO ₂ % -30					
CO % -18					
Density: gm/cc 2.04					
Melting Point: °C					
Freezing Point: °C					
Boiling Point: °C					
Refractive Index, n ₂₀ ^D					
n ₂₅ ^D					
n ₃₀ ^D					
Vacuum Stability Test:					
cc/40 Hrs, at					
90°C					
100°C					
120°C					
135°C					
150°C					
200 Gram Bomb Sand Test: (f)					
Sand, gm 27.4 25.3					
Black powder fuse 17.0					
Sensitivity to Initiation:					
Minimum Detonating Charge, gm					
Mercury Fulminate					
Lead Azide 0.20 0.30					
Tetryl 0.10					
Ballistic Mortar, % TNT:					
Trauzl Test, % TNT:					
Plate Dent Test:					
Method					
Condition					
Confined					
Density, gm/cc					
Brisance, % TNT					
Detonation Rate:					
Confinement					
Condition					
Charge Diameter, in.					
Density, gm/cc					
Rate, meters/second					

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Blue Principal Uses: Primary explosive Method of Loading: Pressed																								
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Loading Density: <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: left;">gm/cc</th> <th style="text-align: left;">psi x 10³</th> <th style="text-align: left;">(c)</th> </tr> </thead> <tbody> <tr> <td>10</td> <td>20</td> <td>40</td> </tr> <tr> <td>1.49</td> <td>1.63</td> <td>1.74</td> </tr> <tr> <td></td> <td></td> <td>1.86</td> </tr> </tbody> </table>	gm/cc	psi x 10 ³	(c)	10	20	40	1.49	1.63	1.74			1.86												
gm/cc	psi x 10 ³	(c)																							
10	20	40																							
1.49	1.63	1.74																							
		1.86																							
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Storage: <div style="display: flex; justify-content: space-between;"> Method Wet </div> <div style="display: flex; justify-content: space-between;"> Hazard Class (Quantity-Distance) Class 9 </div> <div style="display: flex; justify-content: space-between;"> Compatibility Group Group M </div> <div style="display: flex; justify-content: space-between;"> Exudation None </div> Stab Sensitivity: (c) <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: left;">Density <u>gm/cc</u></th> <th colspan="3" style="text-align: left;">Firing Point (inch-ounces)</th> </tr> <tr> <th></th> <th style="text-align: center;"><u>0%</u></th> <th style="text-align: center;"><u>50%</u></th> <th style="text-align: center;"><u>100%</u></th> </tr> </thead> <tbody> <tr> <td>1.49</td> <td style="text-align: center;">9</td> <td style="text-align: center;">11</td> <td style="text-align: center;">15</td> </tr> <tr> <td>1.63</td> <td style="text-align: center;">8.5</td> <td style="text-align: center;">10</td> <td style="text-align: center;">12</td> </tr> <tr> <td>1.74</td> <td style="text-align: center;">6</td> <td style="text-align: center;">7</td> <td style="text-align: center;">9</td> </tr> <tr> <td>1.86</td> <td style="text-align: center;">4</td> <td style="text-align: center;">5</td> <td style="text-align: center;">6</td> </tr> </tbody> </table> Heat of: <div style="display: flex; justify-content: space-between;"> Explosion, cal/gm 432 </div> Specific Heat, cal/gm/°C <div style="display: flex; justify-content: space-between;"> Temp range 0°-30°C 0.155 </div> <div style="display: flex; justify-content: space-between;"> Wt of sample, gm 0.8910 </div>	Density <u>gm/cc</u>	Firing Point (inch-ounces)				<u>0%</u>	<u>50%</u>	<u>100%</u>	1.49	9	11	15	1.63	8.5	10	12	1.74	6	7	9	1.86	4	5	6
Density <u>gm/cc</u>	Firing Point (inch-ounces)																								
	<u>0%</u>	<u>50%</u>	<u>100%</u>																						
1.49	9	11	15																						
1.63	8.5	10	12																						
1.74	6	7	9																						
1.86	4	5	6																						

Preparation: (a)

Five grams of 5-aminotetrazole are dissolved in a mixture of 200 ml of water and 70 ml of concentrated HCl. Enough kerosene or nujol (which gives a slightly cleaner product) is added to provide a layer of oil approximately 1/4" thick on the surface. With only moderate stirring and external cooling to 10°-15°C, a solution of 5 grams of sodium nitrite in 70 cc of water is added rapidly by means of a burette extending below the oil layer. Immediately after this addition, a solution of 5 gms of cupric chloride in a minimum amount of water is added all at once, and stirring is continued for about 1 hour. The reaction mixture is allowed to stand for a few minutes till the bright blue copper salt separates. The oil is removed by decantation and may be reused. The salt is filtered; washed with water, alcohol, and ether; and dried - giving a yield of 6 grams or 74%.

Origin:

The copper salt of 5-chlorotetrazole was first described in 1929 by R. Stolle (with E. Schick, F. Henke-Stark and L. Krauss) who prepared the compound by reaction of the diazonium chloride of 5-aminotetrazole with copper chloride (Ber 62A, 1123).

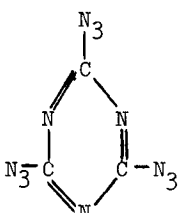
References:¹²

(a) R. J. Gaughran and J. V. R. Kaufman, Synthesis and Properties of Halotetrazole Salts, PATR No. 2136, February 1955.

(b) A. M. Anzalone, J. E. Abel and A. C. Forsyth, Characteristics of Explosive Substances for Application in Ammunition, PATR No. 2179, May 1955.

(c) A. C. Forsyth, Pfc, S. Krasner and R. J. Gaughran, Development of Optimum Explosive Trains. An Investigation Concerning Stab Sensitivity versus Loading Density of Some Initiating Compounds, PATR No. 2146, February 1955.

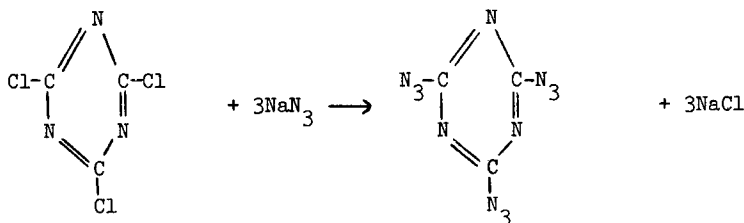
¹²See footnote 1, page 10.

Composition: % C 17.6 N 82.4  C/H Ratio	Molecular Weight: (C ₃ N ₁₂) 204 Oxygen Balance: CO ₂ % -47.1 CO % -23.5 Density: gm/cc Crystal 1.54 Melting Point: °C 94 Freezing Point: °C
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 1 kg wt 7 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. - Sample Wt, mg -	Boiling Point: °C Refractive Index, n ₂₀ ^D n ₂₅ ^D n ₃₀ ^D
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C
Rifle Bullet Impact Test: Trials % Explosions Partial Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm 32.2 Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate - Lead Azide 0.20 Tetryl 0.10
Explosion Temperature: °C Seconds, 0.1 (no cap used) 252 1 5 10 15 20	Ballistic Mortar, % TNT:
75°C International Heat Test: % Loss in 48 Hrs	Trauzl Test, % TNT:
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT
Flammability Index:	Detonation Rate: Confinement - Condition - Charge Diameter, in. 0.3 Density, gm/cc 1.15 Rate, meters/second 5550-5600
Hygroscopicity: %	
Volatility: Decomposes above 100°C	

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Color: Colorless Principal Uses: Not used because of difficulty in controlling sensitivity.
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Method of Loading: Pressed Loading Density: gm/cc <div style="display: flex; justify-content: space-between;"> At 200 atmospheres 1.4 </div> <div style="display: flex; justify-content: space-between;"> At 800 atmospheres 1.5 </div> Storage: Method <div style="display: flex; justify-content: space-between;"> Hazard Class (Quantity-Distance) Class 9 </div> Compatibility Group <div style="display: flex; justify-content: space-between;"> Exudation None </div>

Preparation:

By the reaction of cyanuric chloride with an aqueous solution of sodium azide:



Recrystallization should be avoided as it leads to very large crystals which explode when broken.

Origin:

Cyanuric Triazide was prepared in 1847 by Cahours from chlorine and methyl cyanate. Later James improved the process (JCS 51, 268 (1887) and in 1921 E. Ott patented the preparation from cyanuric chloride and sodium azide (Ref b) Taylor and Rinkenbach prepared cyanuric triazide in a pure state and determined its properties (Ref c).

Initiating Efficiency:

Reported to be more efficient than lead azide. Capable of initiating Explosive D.

Solubility:

Insoluble in water; readily soluble in hot ethanol, acetone, benzene, and ether.

Heat of:

Formation, cal/gm -1090 to -1138

References:¹³

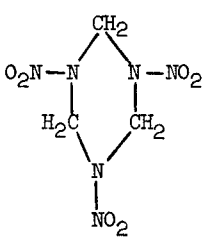
(a) A. H. Blatt, Compilation of Data on Organic Explosives, OSRD Report No. 2014, 29 February 1944.

(b) Ott and Ohse, Ber 54, 179 (1921).

(c) Taylor and Rinkenbach, Bureau of Mines, RI 2513 (1923).

Taylor and Rinkenbach, J Frank Inst 204, 369 (1927).

¹³See footnote 1, page 10.

Composition: % C 16.3 H 2.7 N 37.8 O 43.2 C/H Ratio 0.095				Molecular Weight: ($C_3H_6N_6O_6$) 222
		Oxygen Balance: CO ₂ % -22 CO % 0.0		
		Density: gm/cc Crystal 1.82		
		Melting Point: °C 204		
		Freezing Point: °C		
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 32 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 8 Sample Wt, mg 18		Boiling Point: °C		
		Refractive Index, n_{20}^D n_{25}^D n_{30}^D		
Friction Pendulum Test: Steel Shoe Explodes Fiber Shoe Unaffected		Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.7 120°C 0.9 135°C - 150°C 2.5		
Rifle Bullet Impact Test: Trials Explosions 100 Partial 0 Burned 0 Unaffected 0		200 Gram Bomb Sand Test: Sand, gm 60.2		
Explosion Temperature: °C Seconds, 0.1 (no cap used) 405 1 316 5 Decomposes 260 10 240 15 235 20 -		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.19* Lead Azide 0.05* Tetryl - * Alternative initiating charges.		
		Ballistic Mortar, % TNT: (a) 150		
		Trauzl Test, % TNT: (b) 157		
75°C International Heat Test: % Loss in 48 Hrs 0.03		Plate Dent Test: (c) Method A Condition Pressed Confined Yes Density, gm/cc 1.50 Brisance, % TNT 135		
100°C Heat Test: % Loss, 1st 48 Hrs 0.04 % Loss, 2nd 48 Hrs 0.00 Explosion in 100 Hrs None		Detonation Rate: Confinement None Condition Pressed Charge Diameter, in. 1.0 Density, gm/cc 1.65 Rate, meters/second 8180		
Flammability Index: (d) 278				
Hygroscopicity: % 25°C, 100% RH 0.02				
Volatility: Nil				

*Name given by Clarence J. Bain of Picatinny Arsenal. Germans call it Hexogen; Italians call it T4; British, RDX.

Booster Sensitivity Test: Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc	Decomposition Equation: Oxygen, atoms/sec (i) (Z/sec) 10 ^{18.5} Heat, kilocalorie/mole 47.5 (ΔH, kcal/mol) Temperature Range, °C 213-299 Phase Liquid																				
Heat of: Combustion, cal/gm 2285 Explosion, cal/gm 1280 Gas Volume, cc/gm 908 Formation, cal/gm -96 Solution, cal/mol (28-55% HNO ₃) 7.169* *Assuming cyclonite unimolecular	Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bombs: Plate Thickness, inches 1 1¼ 1½ 1¾																				
Specific heat: cal/gm/°C <table><thead><tr><th colspan="2">°C</th><th colspan="2">°C</th></tr></thead><tbody><tr><td>20</td><td>0.298</td><td>100</td><td>0.406</td></tr><tr><td>40</td><td>0.331</td><td>120</td><td>0.427</td></tr><tr><td>60</td><td>0.360</td><td>140</td><td>0.446</td></tr><tr><td>80</td><td>0.384</td><td></td><td></td></tr></tbody></table>	°C		°C		20	0.298	100	0.406	40	0.331	120	0.427	60	0.360	140	0.446	80	0.384			Bomb Drop Test: T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete: Max Safe Drop, ft 500-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order 1000-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order
°C		°C																			
20	0.298	100	0.406																		
40	0.331	120	0.427																		
60	0.360	140	0.446																		
80	0.384																				
Burning Rate: cm/sec																					
Thermal Conductivity: cal/sec/cm/°C 1.263 (h) Density, gm/cc 1.533 6.91 x 10 ⁻⁴ 6.98 x 10 ⁻⁴																					
Coefficient of Expansion: Linear, %/°C Volume, %/°C																					
Hardness, Mohs' Scale: 2.5																					
Young's Modulus: E', dynes/cm ² E, lb/inch ² Density, gm/cc																					
Compressive Strength: lb/inch ²																					
Vapor Pressure: °C mm Mercury																					

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones Hole Volume Hole Depth
	Color:

Solubility of Cyclonite; gm/100 gm of the following substances: (j)

<u>Water</u>		<u>Alcohol</u>		<u>Acetone</u>		<u>Benzene</u>		<u>Toluene</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
30	0.005	0	0.040	0	4.4	20	0.05	0	0.015
50	0.025	20	0.105	20	7.3	40	0.09	20	0.02
70	0.076	40	0.240	40	11.5	60	0.20	40	0.05
90	0.19	60	0.579	60	18.	80	0.41	60	0.13
100	0.28	78	1.195					80	0.30
								100	0.65
<u>Ethyl acetate</u>		<u>Carbon tetrachloride</u>		<u>Methanol</u>		<u>Ether</u>		<u>TNT</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
28	2.9	50	0.005	0	0.14	10	0.05	80	4.4
94	18.	60	0.007	20	0.23	20	0.056	85	5.0
		70	0.009	40	0.47	30	0.076	90	5.55
				60	1.1			95	6.2
								100	7.0
								105	7.9
<u>Isoamyl alcohol</u>		<u>Methyl acetate</u>		<u>β-Ethoxyethyl acetate</u>		<u>Chlorobenzene</u>		<u>Trichloroethylene</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
0	0.02	20	2.9	20	0.15	20	0.33	20	0.20
20	0.03	30	3.3	30	0.16	30	0.44	30	0.22
40	0.065	40	4.1	40	0.19	40	0.56	40	0.24
60	0.22	50	5.6	50	0.25	50	0.74	50	0.26
80	0.54								
100	1.35								
<u>Tetra-chloroethane</u>		<u>Isopropanol</u>		<u>Isobutanol</u>		<u>Chloroform</u>		<u>Mesityloxide</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
38	0.09	38	0.18	20	0.0	20	0.01	27	3.2
								97	12.2
<u>Cyclo-hexanone</u>		<u>Nitro-benzene</u>		<u>Nitro-ethane</u>		<u>Cyclo-pentanone</u>		<u>Acetonitrile</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
25	12.7	25	1.5	23	3.6	28	11.5	28	11
97	25	97	12.4	93	19	90	37	82	33
<u>Methyl ethyl ketone</u>									
<u>°C</u>	<u>%</u>								
28	5.6								
95	14								

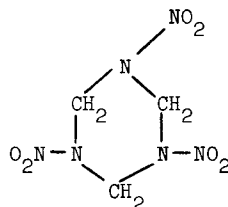
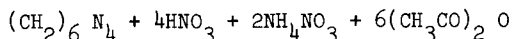
Solubility of Cyclonite, Holston Lot E-2-5 in Various Solvents:

<u>Solvent</u>	<u>Boiling Point, °C</u>	<u>Grade or Source*</u>	<u>Solubility</u> <u>gm/100 gm</u> <u>Solvent</u>		<u>Crystalline Form</u>
			<u>28°C</u>	<u>Heated</u>	
Acetone	56	CP	8.2	16.5 at 60°C	hexagonal-thick
Cyclohexanone	155.6	CP	13.0	24.0 at 93°C	cubic (massive form)
Nitromethane	100.8		1.5	12.4 at 97°C	plates
Acetonitrile	81.6	Miacet Chem. Co.	11.3	33.4 at 93°C	plates
1-Nitropropane	126.5	EK Pract	1.4	10.6 at 93°C	short needles
2-Nitropropane	120	EK Pract	2.3	11.6 at 93°C	short needles
2,4-Pentanedione	140.5	Carbide & Carbon	2.9	18.3 at 93°C	flat prisms
Methylisobutylketone	115.8		2.4	9.6 at 93°C	long prisms
n-Propylacetate	101.6	EK Red Label	1.5	6.0 at 93°C	long prisms, some cubic
n-Butylformate	105.6	EK Red Label	1.4	4.6 at 93°C	long prisms
Ethyl acetate	77.1	Baker's CP	2.0	6.1 at boil.	hexagonal plates
n-Propylpropionate	121	EK Red Label	0.8	1.6 at 93°C	short prisms, some cubic
Butylacetate	126.5	EK Technical	1.1	4.0 at 93°C	long prisms
Methylethylketone	79.6		5.6	13.9 at boil.	coarse plates
Nitroethane	114.2	EK Red Label	3.6	19.5 at 93°C	plates
Isopropylacetate	88-90	CP	1.1	3.2 at boil.	long prisms
Mesityloxide	128	EK Red Label	4.8	14.5 at 93°C	plates
n-Amylacetate	146	CP	1.0	2.1 at 93°C	prisms
Dimethylcarbonate	88-91	EK Red Label	1.4	6.6 at boil.	plates
Diethylcarbonate	125-126.5	EK Red Label	0.7	3.2 at 93°C	prisms
Isoamylacetate	132	CP	1.2	3.6 at 93°C	prisms
Ethylpropionate	98-100	EK Red Label	3.0	10.7 at 93°C	fairly thick hex plates
Methyl-n-butyrate	101.5-103.5	EK Red Label	1.2	4.9 at 93°C	needles
Cyclopentanone	130.6	EK Red Label	11.5	39.0 at 93.5°C	hexagonal plates
Acrylonitrile	77.3	Cyanamid Co.	4.0	16.4 at boil.	flat plates
Methylcellosolveacetate	144.5	Carbide & Carbon	1.6	8.8 at 93°C	massive hexagons and prisms

* EK, Eastman Kodak; Pract, practical.

Preparation:

(Summary Technical Report of the NDRC, Div 8, Vol 1)



Ammonium nitrate and acetic anhydride are placed in a flask and, while the mixture is stirred at 75°C, the following three liquids are introduced concurrently and proportionately: acetic anhydride, concentrated nitric acid, and a solution of hexamine in glacial acetic acid. The final mixture is held for a short time at 75°C, diluted with water to 30% acetic acid, and simmered to hydrolyze unstable reaction by-products, which are a mixture of various nitrated and acetylated derivatives of hexamine fragments. After simmering, the slurry is cooled and the precipitated cyclonite removed by filtration. The yield is 78% of the theoretical amount (2 moles) of cyclonite melting at 199°C. By dissolving the ammonium nitrate in the nitric acid, a continuous process, based on 3 liquids, is possible.

The product is recrystallized from acetone, or cyclohexanone, to (a) remove acidity, (b) control particle size and (c) to produce stable β -HMX. The preparative procedure described above, the Bachmann or Combination process, yields cyclonite containing 3-8% HMX.

Origin:

First prepared by Henning in 1899 (German Patent 104,280) and later by von Hertz (U. S. Patent 1, 402,693) in 1922 who recognized its value as an explosive. Not used on a large scale in explosive ammunition until World War II.

Destruction by Chemical Decomposition:

Cyclonite (RDX) is decomposed by adding it slowly to 25 times its weight of boiling 5% sodium hydroxide. Boiling should be continued for one-half hour.

References:¹⁴

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) Ph. Naoum, Z. ges Schiess Sprengstoffw, pp. 181, 229, 267 (27 June 1932).
- (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (d) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.

¹⁴See footnote 1, page 10.

(e) Armament Research Department (Woolwich), Solubility of RDX in Nitric Acid (ARD Expl Rpt 322/43 September 1943).

(f) Report AC-2587.

(g) International Critical Tables
Land. Bornst.

B. T. Fedoroff et al, A Manual for Explosives Laboratories, Lefax Society Inc, Philadelphia, 1943-6.

(h) E. Hutchinson, The Thermal Sensitiveness of Explosives. The Thermal Conductivity of Explosive Materials, AC 2861, First Report, August 1942.

(i) R. J. Finkelstein and G. Gamow, Theory of the Detonation Process, NAVORD Report No. 90-46, 20 April 1947.

(j) International Critical Tables.

(k) W. F. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Different Temperatures, PATR No. 2383, November 1956.

(l) Also see the following Picatinny Arsenal Technical Reports on Cyclonite:

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
1170	1211	582	863	1184	65	1236	857	1438	709
1290	1241	1342	1193	1414	1175	1316	1207	1458	1379
1360	1311	1352	1293	1454	1185	1416	1427	1498	1429
1450	1421	1372	1433	1614	1435	1446	1437	1578	1449
1760	1481	1402	1483	1634	1445	1466	1517	1838	1469
1980	1561	1452	1503	2024	1715	1476	1617	1958	1709
2100	1611	1492	1693	2154	1855	1516	1687	1958	1909
	1651	1532	1713	2204	1885	1556	1737	2008	2059
	1741	2062	1793		1915	1756	1747	2028	2179
	1751	2112	1923		1935	1766	1787	2178	
	1761				2095	1796	1797	2198	
	2131				2125	1836	1957		
	2151				2205	1936	2147		
						1956	2227		
						2016			
						2056			
						2176			

Composition: % RDX 75 TNT 25 C/H Ratio	Molecular Weight: 224	
	Oxygen Balance: CO ₂ % -35 CO % - 6	
	Density: gm/cc	Cast 1.71
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	Boiling Point: °C	
	Refractive Index, n_{20}^D n_{25}^D n_{30}^D	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.23 120°C 0.41 135°C - 150°C -	
Rifle Bullet Impact Test: Trials Explosions % 30 Partials Smokes 40 Burned 0 Unaffected 30	200 Gram Bomb Sand Test: Sand, gm	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	
	Ballistic Mortar, % TNT:	
	Trauzl Test, % TNT:	
	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
	Detonation Rate: Confinement None None Condition Cast Cast Charge Diameter, in. 1.0 1.0 Density, gm/cc 1.70 1.71 Rate, meters/second 8035 7938	
75°C International Heat Test: % Loss in 48 Hrs		
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs		
Flammability Index:		
Hygroscopicity: %		
Volatility:		

Booster Sensitivity Test: Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc	Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH, kcal/mol) Temperature Range, °C Phase																				
Heat of: Combustion, cal/gm 2625* Explosion, cal/gm 1225* Gas Volume, cc/gm 862 Formation, cal/gm Fusion, cal/gm (h) 5.0 *Calculated from composition of mixture.	Armor Plate Impact Test: 60 mm Mortar Projectile: 50 % Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bombs: Plate Thickness, inches 1 1¼ 1½ 1¾																				
Specific Heat: cal/gm/°C (h) <table><tr><td>°C</td><td></td><td>°C</td><td></td></tr><tr><td>-75</td><td>0.220</td><td>75</td><td>0.352</td></tr><tr><td>0</td><td>0.225</td><td>85</td><td>0.325</td></tr><tr><td>25</td><td>0.254</td><td>90</td><td>0.332</td></tr><tr><td>50</td><td>0.296</td><td>100</td><td>0.351</td></tr></table>	°C		°C		-75	0.220	75	0.352	0	0.225	85	0.325	25	0.254	90	0.332	50	0.296	100	0.351	
°C		°C																			
-75	0.220	75	0.352																		
0	0.225	85	0.325																		
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Burning Rate: cm/sec																					
Thermal Conductivity: cal/sec/cm/°C																					
Coefficient of Expansion: Linear, %/°C Volume, %/°C																					
Hardness, Mohs' Scale:																					
Young's Modulus: E', dynes/cm² E, lb/inch² Density, gm/cc																					
Compressive Strength: lb/inch²																					
Vapor Pressure: °C mm Mercury	Bomb Drop Test: T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete: Max Safe Drop, ft 500-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order 1000-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order																				

<p>Fragmentation Test:</p> <p>90 mm HE, M71 Projectile, Lot WC-91:</p> <p>Density, gm/cc 1.72</p> <p>Charge Wt, lb 2.22</p> <p>Total No. of Fragments:</p> <p>For TNT 703</p> <p>For Subject HE 1514</p> <p>3 inch HE, M42A1 Projectile, Lot KC-5:</p> <p>Density, gm/cc</p> <p>Charge Wt, lb</p> <p>Total No. of Fragments:</p> <p>For TNT</p> <p>For Subject HE</p> <p>Fragment Velocity: ft/sec</p> <p>At 9 ft</p> <p>At 25½ ft</p> <p>Density, gm/cc</p>	<p>Shaped Charge Effectiveness, TNT = 100:</p> <p>Glass Cones Steel Cones</p> <p>Hole Volume</p> <p>Hole Depth</p> <p>Color: Yellow-buff</p> <p>Principal Uses: Shaped charge bomb especially fragmentation; HE projectiles; grenades</p> <p>Method of Loading: Cast</p> <p>Loading Density: gm/cc 1.71</p> <p>Storage:</p> <p>Method Dry</p> <p>Hazard Class (Quantity-Distance) Class 9</p> <p>Compatibility Group Group I</p> <p>Exudation</p>
<p>Blast (Relative to TNT): (d)</p> <p>Air:</p> <p>Peak Pressure 111</p> <p>Impulse 126</p> <p>Energy --</p> <p>Air, Confined:</p> <p>Impulse</p> <p>Under Water:</p> <p>Peak Pressure</p> <p>Impulse</p> <p>Energy</p> <p>Underground:</p> <p>Peak Pressure</p> <p>Impulse</p> <p>Energy</p>	<p>Preparation: See Composition B</p> <p>Origin: Developed by the British between World Wars I and II and standardized in the United States early in World War II.</p> <p>Black Modulus at Room Temperature (25°-30°C):</p> <p>Dynes/cm² x 10⁻¹⁰ 3.09</p> <p>Density, gm/cc 1.74</p> <p>Absolute Viscosity, poises:*</p> <p>Temp, 85°C 210**</p> <p>90°C --</p> <p>Efflux Viscosity, Saybolt Seconds:</p> <p>Temp, 85°C 9-14</p> <p>* Compositions using Spec Grade Type A, Class A RDX.</p> <p>** Composition prepared using RDX of optimum particle size.</p>

Composition: % RDX 70 TNT 30 C/H Ratio	Molecular Weight: 224	
	Oxygen Balance: CO ₂ % -37 CO % - 8	
	Density: gm/cc	Cast 1.71
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 60 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 14 Sample Wt, mg 20	Boiling Point: °C	
	Refractive Index, n ₂₀ ^D n ₂₅ ^D n ₃₀ ^D	
	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 0.86 135°C 150°C	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	200 Gram Bomb Sand Test: Sand, gm 56.6	
Rifle Bullet Impact Test: Trials % Explosions 30 Partial 30 Burned 0 Unaffected 40	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.21* Lead Azide 0.20* Tetryl *Alternative initiating charges.	
	Ballistic Mortar, % TNT: (a) 135	
Explosion Temperature: °C Seconds, 0.1 (no cap used) - 1 - 5 Decomposes 265 10 15 20	Trauzl Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: (b) Method B Condition Cast Confined No Density, gm/cc 1.725 Brisance, % TNT 136	
100°C Heat Test: % Loss, 1st 48 Hrs 0.07 % Loss, 2nd 48 Hrs 0.08 Explosion in 100 Hrs None	Detonation Rate: Confinement None Condition Cast Charge Diameter, in. 1.0 Density, gm/cc 1.73 Rate, meters/second 8060	
Flammability Index:		
Hygroscopicity: % Nil		
Volatility: Nil		

Fragmentation Test:	Shaped Charge Effectiveness, TNT = 100:																					
90 mm HE, M71 Projectile, Lot WC-91:	<table><tr><td></td><td>Glass Cones</td><td>Steel Cones</td><td>(e)</td></tr><tr><td>Density, gm/cc</td><td>1.71</td><td></td><td></td></tr><tr><td>Charge Wt, lb</td><td>2.213</td><td></td><td></td></tr></table>		Glass Cones	Steel Cones	(e)	Density, gm/cc	1.71			Charge Wt, lb	2.213			<table><tr><td>Hole Volume</td><td></td><td></td><td></td></tr><tr><td>Hole Depth</td><td></td><td>130</td><td></td></tr></table>	Hole Volume				Hole Depth		130	
	Glass Cones	Steel Cones	(e)																			
Density, gm/cc	1.71																					
Charge Wt, lb	2.213																					
Hole Volume																						
Hole Depth		130																				
Total No. of Fragments:	Color:																					
For TNT 703	Yellow-buff																					
For Subject HE 1165																						
3 inch HE, M42A1 Projectile, Lot KC-5:	Principal Uses: Shaped charge bombs: especially fragmentation HE projectiles, grenades																					
Density, gm/cc 1.72																						
Charge Wt, lb 0.923																						
Total No. of Fragments:	Method of Loading:																					
For TNT 514	Cast																					
For Subject HE 828																						
Fragment Velocity: ft/sec	Loading Density: gm/cc 1.71																					
At 9 ft																						
At 25½ ft																						
Density, gm/cc																						
Blast (Relative to TNT): (d)	Storage:																					
Air:	Method Dry																					
Peak Pressure 110	Hazard Class (Quantity-Distance) Class 9																					
Impulse 120	Compatibility Group Group I																					
Energy --	Exudation																					
Air, Confined:	Preparation: See Composition B																					
Impulse	Origin: Developed by the British between World Wars I and II and standardized in the United States early in World War II.																					
Under Water:	Absolute Viscosity, poises:*																					
Peak Pressure	Temp, 85°C --																					
Impulse	90°C 53.2																					
Energy	Efflux Viscosity, Saybolt Seconds:																					
Underground:	Temp, 85°C 5																					
Peak Pressure	Heat of: **																					
Impulse	Combustion, cal/gm 2685																					
Energy	Explosion, cal/gm 1213																					
	Gas Volume, cc/gm 854																					
	* Composition using Spec Grade Type A, Class A RDX.																					
	** Calculated from composition of mixture.																					

Composition: % RDX 55 TNT 35 C/H Ratio	Molecular Weight: 224	
	Oxygen Balance: CO ₂ % -40 CO % - 9	
	Density: gm/cc	Cast 1.71
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	Boiling Point: °C	
	Refractive Index, n_{20}^D n_{25}^D n_{30}^D	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C	
Rifle Bullet Impact Test: Trials % Explosions Partial Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm 55.4	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 270 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	
	Ballistic Mortar, % TNT: (a) 134	
75°C International Heat Test: % Loss in 48 Hrs	Trauzl Test, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
	Detonation Rate: Confinement None Condition Cast Charge Diameter, in. 1.0 Density, gm/cc 1.72 Rate, meters/second 7975	
Flammability Index:		
Hygroscopicity: % Nil		
Volatility: Nil		

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc 1.71 Charge Wt, lb 2.253 Total No. of Fragments: For TNT 703 For Subject HE 1153 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc 1.71 Charge Wt, lb 0.922 Total No. of Fragments: For TNT 514 For Subject HE 769	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones (e) Hole Volume Hole Depth 130 Color: Yellow-buff Principal Uses: Shaped charge bombs; especially fragmentation HE projectiles, grenades Method of Loading: Cast Loading Density: gm/cc 1.71 Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation Preparation: See Composition B Origin: Developed by the British between World Wars I and II and standardized in the United States early in World War II. Eutectic Temperature, °C: 79 gm RDX/100 gm TNT 79°C 4.16 95°C 5.85 Absolute Viscosity, poises:* Temp, 85°C 30.2 90°C 26.0 * Composition using Spec Grade Type A, Class A RDX.
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy Heat of: * Combustion, cal/gm 2755 Explosion, cal/gm 1205 Gas Volume, cc/gm 845 * Calculated from composition of mixture.	

Composition: % RDX 60 TNT 40 C/H Ratio	Molecular Weight: 224	
	Oxygen Balance: CO ₂ % -43 CO % 10	
	Density: gm/cc Cast 1.68	
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 75 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 14 Sample Wt, mg 19	Boiling Point: °C	
	Refractive Index, n ₂₀ ^D n ₂₅ ^D n ₃₀ ^D	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 0.29 135°C 150°C	
Rifle Bullet Impact Test: Trials % Explosions 5 Partials 55 Burned 25 Unaffected 15	200 Gram Bomb Sand Test: Sand, gm 54.6	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 280 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.22* Lead Azide 0.20* Tetryl *Alternative initiating charges.	
75°C International Heat Test: % Loss in 48 Hrs	Ballistic Mortar, % TNT: (a) 1.33	
	Trauzl Test, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Plate Dent Test: (b) Method B Condition Cast Confined No Density, gm/cc 1.72 Brisance, % TNT 132	
	Detonation Rate: Confinement None Condition Cast Charge Diameter, in. 1.0 Density, gm/cc 1.72 Rate, meters/second 7900	
Flammability Index:		
Hygroscopicity: % Nil		
Volatility: Nil		

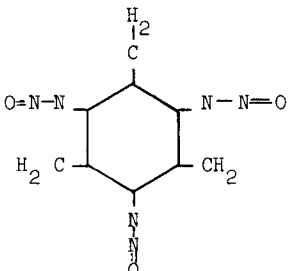
Fragmentation Test:	Shaped Charge Effectiveness, TNT = 100:		
90 mm HE, M71 Projectile, Lot WC-91:	Glass Cones	Steel Cones	(e)
Density, gm/cc	178	162	
Charge Wt, lb	125	148	
Total No. of Fragments:			
For TNT	703		
For Subject HE	998		
3 inch HE, M42A1 Projectile, Lot KC-5:			
Density, gm/cc	1.67		
Charge Wt, lb	0.882		
Total No. of Fragments:			
For TNT	514		
For Subject HE	701		
Fragment Velocity: ft/sec (c)			
At 9 ft	2965		
At 25½ ft	2800		
Density, gm/cc	--		
Blast (Relative to TNT): (d)			
Air:			
Peak Pressure	104		
Impulse	116		
Energy	--		
Air, Confined:			
Impulse			
Under Water:			
Peak Pressure			
Impulse			
Energy			
Underground:			
Peak Pressure			
Impulse			
Energy			
Heat of:	*		
Combustion, cal/gm	2820		
Explosion, cal/gm	1195		
Gas Volume, cc/gm	845		
Compressive Strength: lb/inch²			
1.70 gm/cc	2200-3000		
Color: Yellow-buff			
Principal Uses: Shaped charge bomb; especially fragmentation HE projectiles, grenades			
Method of Loading: Cast			
Loading Density: gm/cc 1.68			
Storage:			
Method Dry			
Hazard Class (Quantity-Distance) Class 9			
Compatibility Group Group I			
Exudation			
Preparation: See Composition B			
Origin: Developed by the British between World Wars I and II and standardized in the United States early in World War II.			
Bulk Modulus at Room Temperature (25°-30°C):			
Dynes/cm ² x 10 ⁻¹⁰ 4.14			
Density, gm/cc 1.72			
Absolute Viscosity, poises:*			
Temp, 85°C 12.3			
90°C --			
* Compositions using Spec Grade Type A, Class A RDX.			

* Calculated from composition of mixture.

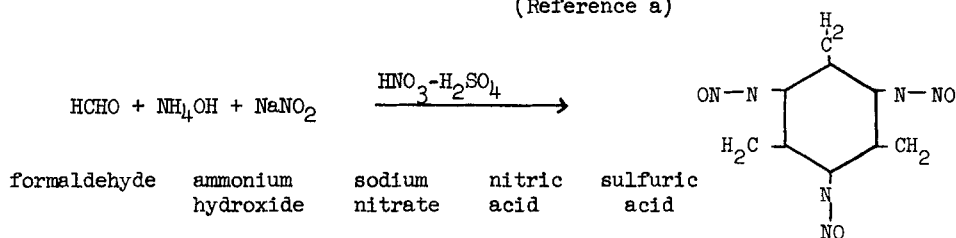
References:¹⁵

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (c) R. W. Drake, Fragment Velocity and Panel Penetration of Several Explosives in Simulated Shells, OSRD Report No. 5622, 2 January 1946.
- (d) V. Philipchuk, Free Air Blast Evaluation of RDX-TNT-Al, RDX-TNT, and TNT-Metal Systems, National Northern Summary Report, NN-P-34, April 1956.
- (e) Eastern Laboratory, du Pont, Investigation of Cavity Effect. Section III, Variation of Cavity Effect with Composition, NDRC Contract W-672-ORD-5723.
- (f) W. S. Cramer, Bulk Compressibility Data on Several High Explosives, NAVORD Report No. 4380, 15 September 1956.
- (g) Also see the following Picatinny Arsenal Technical Reports on Cyclotols:
- | <u>0</u> | <u>1</u> | <u>2</u> | <u>3</u> | <u>4</u> | <u>5</u> | <u>6</u> | <u>7</u> | <u>8</u> | <u>9</u> |
|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| 1290 | 1651 | 1482 | 1483 | 1824 | 1435 | 1476 | 1427 | 1398 | 1469 |
| 1530 | 1741 | | 1793 | 1834 | 1585 | 1756 | 1507 | 1488 | 1509 |
| | | | 1983 | 1944 | | 1796 | 1747 | 1838 | 1709 |
| | | | | 2004 | | 1876 | | | |
- (h) C. Lenchitz, W. Beach and R. Valicky, Enthalpy Changes, Heat of Fusion and Specific Heat of Basic Explosives, PATR No. 2504, January 1959.

¹⁵See footnote 1, page 10.

Composition: % C 20.6 H 3.5 N 48.3 O 27.6 C/H Ratio 0.12		Molecular Weight: ($C_3H_6N_6O_3$) 174
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 15 to 22 Sample Wt, mg 17 to 20	Oxygen Balance: CO ₂ % -55 CO % -28	Density: gm/cc
		Melting Point: °C 105 to 107
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	Freezing Point: °C	Boiling Point: °C
		Refractive Index, n_{20}^D n_{25}^D n_{30}^D
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected	Vacuum Stability Test: (c) cc/40 Hrs, at 90°C 0.20 100°C 9.19 3.71* *Average value of 5 gm sample twice recrystallized from isoamyl alcohol.	200 Gram Bomb Sand Test: Sand, gm 59.2 54.1
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 220 10 15 20		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.200** Lead Azide 0.100** **Alternative initiating charges.
75°C International Heat Test: % Loss in 48 Hrs	Ballistic Mortar, % TNT: 130 Trauzl Test, % TNT:	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT
100°C Heat Test: % Loss, 1st 48 Hrs 8.79 % Loss, 2nd 48 Hrs 2.98 Explosion in 100 Hrs None		Detonation Rate: (b) Confinement None Condition Cast Charge Diameter, in. 1.2 Density, gm/cc 1.42 Rate, meters/second 7000 to 7300
Flammability Index:		
Hygroscopicity: % 30°C, 90% RH 0.02		
Volatility:		

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones Hole Volume Hole Depth Color: Yellow Principal Uses: Ingredient of projectile filler Method of Loading: Pressed or cast with added melting point depressants Loading Density: gm/cc See below																
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group M Exudation None																
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Density at Various Pressures: (b) <table> <thead> <tr> <th><u>lb/inch²</u></th><th><u>gm/cc</u></th></tr> </thead> <tbody> <tr><td>2,420</td><td>1.10</td></tr> <tr><td>4,830</td><td>1.23</td></tr> <tr><td>9,650</td><td>1.37</td></tr> <tr><td>14,500</td><td>1.44</td></tr> <tr><td>24,200</td><td>1.53</td></tr> <tr><td>33,800</td><td>1.57</td></tr> <tr><td>42,500</td><td>1.59</td></tr> </tbody> </table> Heat of: Combustion, cal/gm 3158 Explosion, cal/gm 876 Formation, cal/gm -914	<u>lb/inch²</u>	<u>gm/cc</u>	2,420	1.10	4,830	1.23	9,650	1.37	14,500	1.44	24,200	1.53	33,800	1.57	42,500	1.59
<u>lb/inch²</u>	<u>gm/cc</u>																
2,420	1.10																
4,830	1.23																
9,650	1.37																
14,500	1.44																
24,200	1.53																
33,800	1.57																
42,500	1.59																

Preparation of Hexahydro-1,3,5-Trinitroso-s-triazine Cyclotrimethylene Trinitrosamine:
(Reference a)

An ammoniacal solution of an amine is prepared by adding aqueous formaldehyde to ammonium hydroxide. The rate of addition of formaldehyde is regulated to maintain a solution temperature of 30° to 35°C.

Sodium nitrite is dissolved in water and the solution or slurry is then poured into the previously prepared amine-ammonia solution and totally dissolved by stirring. This solution is chilled to below 0°C.

Into a mixed acid solution, previously prepared by dissolving concentrated nitric acid in water and adding concentrated sulfuric acid, all chilled to -9°C, there is added the cold amine-nitrite solution below the surface of the acid mixture. The addition is regulated to take 20 to 30 minutes.

The resulting foamy head of cyclotrimethylene trinitrosamine is allowed to sit over the icy spent liquor for 1/2 hour and is then collected on a sintered glass funnel and washed to neutrality. The moist cyclotrimethylene trinitrosamine is removed from the funnel and air-dried on filter paper. The dry crude product melts at 106° to 107°C. Recrystallization from isoamyl alcohol gives a pure compound melting at 105° to 107°C.

Origin:

Cyclotrimethylene trinitrosamine was discovered in 1888 simultaneously by Griess and Harrow (Ber 21 (1888), p. 2737) and by Mayer (Ber 21 (1888), p. 2883) when sodium nitrite was allowed to react with hexamethylene tetramine in acid solution. This compound was later studied by Duden and Scharff (Ann 288 (1895), p. 218) and by Delépine who determined its heat of formation, which was negative (Bull Soc chim (3) 15 (1896), p. 1199). Because cyclotrimethylene trinitrosamine could be made at first in very poor yield only, it was a long time before it received consideration for practical application as an explosive. However, the study of cyclotrimethylene trinitrosamine was continued and investigations were made as to its behavior in mixtures with other substances (Prof. D. G. Römer "Report on Explosives," BIOSGP 2-HEC 5742).

Destruction by Chemical Decomposition:

Cyclotrimethylene trinitrosamine is easily decomposed by acid or alkali and even by boiling in water.

High Temperature Decomposition, 0.02 gm in 10 ml Test Tube: (b)

Immersed 10 minutes in bath heated at 5°/minute	
	Temp. °C
(1) Melting begins	105
Decomposition begins	150
Nitrous gas	160
Entire decomposition	170
(2) Some bubbles	110
Very slow decomposition	150
Decomposes in 2 minutes	200
Decomposes in 40 seconds	250
Immediate decomposition	300

Long Term Stability: (b)

Cyclotrimethylene Trinitrosamine loosely packed in covered wooden boxes for six years at ambient temperature and protected from the sun:

1. Explosive showed no color change.
2. Melting point decreased from 104.5° to 104°C.
3. Coefficient of "Utilisation Pratique" decreased from 125.5 to 123.5.
4. An Abel Test at 110°C gave no color to iodine starch paper in 15 minutes.

Fusion Tests, Mixtures of Cyclotrimethylene Trinitrosamine and TNT: (b)

Cyclotrimethylene Trinitrosamine, %	Melting Point, °C
10	74
20	68
30	62
40	55
42	55 (Eutectic)
50	61
60	69
70	77
95	95

Eutectic Composition With TNT: (b) Rate of Detonation, meters/second

42% Cyclotrimethylene Trinitrosamine 7,000
58% TNT

Reaction of Cyclotrimethylene Trinitrosamine With Other Materials:

(b)

1. Iron powder	Slight reaction
2. Copper powder	Slight reaction
3. Aluminum powder	Slight reaction
4. 2 parts picric acid + 1 part R-Salt	a. Violent decomposition after 2 hours at 10°C b. Violent decomposition after 10 to 15 minutes at 100°C
5. 2 parts nitroglycerin + 1 part R-Salt	No evidence of decomposition after 5 days at 90°C

Detonation Rate:

(b)

Confinement	Paper cartridge
Condition	Pressed
Charge Diameter, in.	1.18
Rate, meters/second	Density, gm/cc
5180	0.85
5760	1.00
6600	1.20
7330	1.40
7600	1.50
7800	1.57

References:¹⁶

(a) Arthur D. Little, Inc. Progress Report No. 106, Fundamental Development of High Explosives, April 1955, Contract No. DAI-19-020-501-ORD(P)-33.

(b) Louis Médard and Maurice Dutour, "Étude Des Propriétés De La Cyclotriméthylène Trinitrosamine," Mém poudr, 37, 1924 (1954).

(c) H. A. Bronner and J. V. R. Kaufman, "Synthesis and Properties of R-Salt," PATR in preparation 1959.

(d) Also see the following Picatinny Arsenal Technical Reports on Cyclotrimethylene Trinitrosamine: 1174, 2179.

¹⁶See footnote 1, page 10.

DBX (Depth Bomb Explosive)

AMCP 706-177

Composition: % Ammonium Nitrate 21 RDX 21 TNT 40 Aluminum 18 C/H Ratio	Molecular Weight: 83	
	Oxygen Balance: CO ₂ % -46 CO % -26	
	Density: gm/cc	Cast 1.68
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 35 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 13 Sample Wt, mg 14	Boiling Point: °C	
	Refractive Index, n _D ²⁰ n _D ²⁵ n _D ³⁰	
	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 6.15 135°C 150°C	
Friction Pendulum Test: Steel Shoe Fiber Shoe	200 Gram Bomb Sand Test: Sand, gm 58.5	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected	Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Ignites 400 10 15 20	
	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.10	
	Ballistic Mortar, % TNT: (a) 146	
	Trauzl Test, % TNT:	
	Plate Dent Test: (b) Method B Condition Cast Confined No Density, gm/cc 1.76 Brisance, % TNT 102	
75°C International Heat Test: % Loss in 48 Hrs	Detonation Rate: (c) Confinement None Condition Cast Charge Diameter, in. 1.6 Density, gm/cc 1.65 Rate, meters/second 6600	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs		
Flammability Index:		
Hygroscopicity: %		
Volatility:		

Booster Sensitivity Test: Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc	(e) Cast 100 1.35 1.76	Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH , kcal/mol) Temperature Range, °C Phase
Heat of: Combustion, cal/gm Explosion, cal/gm Gas Volume, cc/gm Formation, cal/gm Fusion, cal/gm	(d) 1700	Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bombs: Plate Thickness, inches 1 1¼ 1½ 1¾
Specific Heat: cal/gm/°C -5°C, density 1.75 gm/cc	(d) 0.25	
Burning Rate: cm/sec		
Thermal Conductivity: cal/sec/cm/°C Density 1.75 gm/cc	13.2 x 10 ⁻⁴	
Coefficient of Expansion: Linear, %/°C -73°C-75°C Volume, %/°C	4.5 x 10 ⁻⁵	
Hardness, Mohs' Scale:		
Young's Modulus: E', dynes/cm² E, lb/inch² Density, gm/cc	(d) 10.4 x 10 ¹⁰ 1.51 x 10 ⁶ 1.72	
Compressive Strength: lb/inch² (d) Density 1.78 gm/cc	3210-3380	
Vapor Pressure: °C mm Mercury		Bomb Drop Test: T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete: Max Safe Drop, ft 500-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order 1000-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Gray Principal Uses: Depth charge Method of Loading: Cast Loading Density: gm/cc 1.61-1.69
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation
Blast (Relative to TNT): (d) Air: Peak Pressure 118 Impulse 127 Energy 138 Air, Confined: Impulse Under Water: Peak Pressure -- Impulse -- Energy 136 Underground: Peak Pressure Impulse Energy	Preparation: DBX can be manufactured by slowly adding water-wet RDX to molten TNT melted in a steam-jacketed kettle equipped with a stirrer. When all the water has evaporated, ammonium nitrate is added and with heating and stirring continued, grained aluminum is added. The mixture is cooled with stirring continued to maintain uniformity and when suitable for pouring the mixture is cast. DBX can also be made by adding 21% ammonium nitrate and 18% aluminum to 42% cyclotol or Composition B of 50/50 RDX/TNT content plus 19% of TNT previously melted at about 100 °C.

Origin:

DBX was developed and used by the United States and Great Britain during World War II.

References:¹⁷

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(c) G. H. Messerly, The Rate of Detonation of Various Explosive Compounds, OSRD Report No. 1219, 22 February 1943.

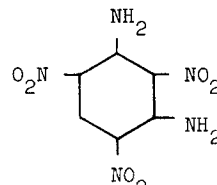
M. D. Hurwitz, The Rate of Detonation of Various Compounds and Mixtures, OSRD Report No. 5611, 15 January 1946.

(d) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.

(e) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Teteryl in Boosters, NOL Memo 10,303, 15 June 1949.

(f) Also see the following Picatinny Arsenal Technical Reports on DBX: 1585 and 1635.

¹⁷See footnote 1, page 10.

Composition: % C 29.6 H 2.1 N 28.8 O 39.5 C/H Ratio 0.380		Molecular Weight: (C ₆ H ₅ N ₅ O ₆) 243	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 18 Sample Wt, mg 9		Oxygen Balance: CO ₂ % CO %	
		Density: gm/cc Crystal 1.83	
		Melting Point: °C (a) 290	
		Freezing Point: °C	
		Boiling Point: °C	
		Refractive Index, n ₂₀ ^D n ₂₅ ^D n ₃₀ ^D	
		Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C	
			200 Gram Bomb Sand Test: Sand, gm 46.6
Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate ---- Lead Azide 0.20 Tetryl 0.10			
	Ballistic Mortar, % TNT: 100		
	Friction Pendulum Test: Steel Shoe Fiber Shoe		
			Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT
Detonation Rate: Confinement None Condition Pressed Charge Diameter, in. 0.5 Density, gm/cc 1.65 Rate, meters/second 7500			
	Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 10 15 20		
75°C International Heat Test: % Loss in 48 Hrs			
		100°C Heat Test: % Loss, 1st 48 Hrs 0.00 % Loss, 2nd 48 Hrs 0.4 Explosion in 100 Hrs None	
	Flammability Index:		
Hygroscopicity: %			
		Volatility:	

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-3: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Color: Yellow
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Principal Uses:
	Method of Loading: Pressed
	Loading Density: gm/cc At 50,000 psi 1.65
	Storage: Method Dry Hazard Class (Quantity-Distance) Compatibility Group Exudation None
	Cook-Off Temperature: °C 320 Time, minutes 8 Heat of: Explosion, cal/gm 2876

Preparation:

Fifty grams (50 gm) of dry styphnic acid was added to 200 gm of anhydrous pyridine with stirring. The resulting slurry was stirred for an additional 30 minutes. The yellow product, dipyridinium styphnate, was collected by filtration and washed with approximately 100 milliliters of diethyl ether. The product was dried over phosphorus (V) oxide, at room temperature, for 5 hours. Yield of 77 gm (94%), melting point 168° to 170°C (literature melting point 173°C).

To 50 milliliters of phosphorus oxytrichloride, 29.8 gm of the dipyridinium styphnate were added in small portions, with stirring. The reaction mixture was then warmed on a steam bath for 15 minutes. This solution was quenched in 500 gm of ice water. The light yellow precipitate was separated by filtration and washed with water until the washing was neutral to litmus. Yield of 1,3-dichloro-2,4,6-trinitrobenzene 20.4 gm (98%), MP 130° to 131°C (literature MP 128°C).

A suspension of 3 gm of 1,3-dichloro-2,4,6-trinitrobenzene in 9 milliliters of absolute methanol was prepared. This slurry was cooled to 0°C, and dry ammonia was bubbled into the stirred suspension. After 20 minutes the reaction mixture was allowed to warm to room temperature, filtered by suction and washed with methanol and ether until a negative Beilstein test for chloride ion was obtained on the washings. Yield of 1,3-diamino-2,4,6-trinitrobenzene 2.5 gm (97%), MP 288° to 290°C (literature MP 285°C).

Origin:

DATNB, also called 2,4,6-trinitro-1,3-diamino-benzol or 2,4,6-trinitro-phenylenediamine-(1,3), was first obtained by Noelting and Collin in 1884 (Ber 17, 260) and also by Barr in 1888 (Ber 21, 1546) from 2,4,6-trinitroresorcin dimethylether in contact with ammoniacal alcohol for several days. J. J. Blanksma obtained the same product in 1902 by reacting either 2-chloro-2,4,6-trinitroanisole or 3-chloro-2,4,6-trinitrophenetol with ammoniacal alcohol (Rec trav chim 21, 324) and from 2,4,6-trinitroresorcin methylethyl ether with ammoniacal alcohol (Rec trav chim 27, 56 (1908)).

Meisenheimer and Patzig in 1906 prepared DATNB in the form of yellow needles, MP 280°C from 1,3,5-trinitrobenzene hydroxylamine and sodium methylate in methyl alcohol (Ber 39, 2540). The product was slightly soluble in glacial acetic acid but poorly soluble in other solvents. It decomposed into NH₃ and 2,4,6-trinitroresorcin when boiled with dilute NaOH or KOH (Beil 13, 60).

Körner and Contardi prepared DATNB by the reaction of either 2,4-dichloro-1,3,5-trinitrobenzene or 2,4-dibromo-1,3,5-trinitrobenzene with ammoniacal alcohol at room temperature or better by heating to 100°C (Atti R. Accad Lincei (5), 171, 473 (1908)); (5) 18 I, 101 (1909)). A method of preparation by prolonged reaction of N-nitro-N-methyl-2,3,4,6-tetranitroaniline with a saturated ammonia solution was reported in 1913 by van Romburgh and Schepers (Akad Amsterdam Versl 22, 297).

C. F. Van Duin obtained DATNB melting at 301°C by reacting a concentrated aqueous ammonia solution with N-nitro-N,N,N-trimethyl-2,4,6-trinitrophenylenediamine-(1,3) or with N-nitro-N-methyl-N-phenyl-2,4,6-trinitrophenylenediamine-(1,3) (Rec trav chim 38, 89-100 (1919)). Later Van Duin and Van Lennep reacted concentrated aqueous ammonia with 2,4,6-trinitro-3-aminoanisole or 2,4,6-trinitro-3-aminophenetol to obtain DATNB melting at 287° to 288°C (Rec trav chim 39, 147-77 (1920)). In 1927 Lorang prepared the same compound by boiling 2,4,6-trinitro-1,3-bis (-nitroethyl ureido) benzene with water or by heating it with ammoniacal alcohol in a tube at 100°C (Rec trav chim 46, 649) (Beil E 17, E II 33).

A recent report describes the preparation of DATNB in two steps from commercially available starting materials. First m-nitroaniline was nitrated with $\text{H}_2\text{SO}_4\text{-HNO}_3$ acid mixture to tetranitroaniline. The crude tetranitroaniline was converted by methanolic ammonia to diaminotrinitro-benzene in a high degree of purity. A conversion of 100 parts of m-nitroaniline into 110 parts of DATNB was obtained by this method, which can easily be carried out on a commercial scale.

Composition: % C 34.3 H 0.9 N 26.7 O 38.1 C/H Ratio 1.056				Molecular Weight: (C ₆ H ₂ N ₄ O ₅) 210	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 4; (1 lb wt) 7 Sample Wt, mg 15				Oxygen Balance: CO ₂ % -61 CO % -15	
Friction Pendulum Test: Steel Shoe Detonates Fiber Shoe Detonates				Density: gm/cc Crystal 1.63	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected				Melting Point: °C 157	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 200 5 195 10 180 15 20				Freezing Point: °C	
75°C International Heat Test: % Loss in 48 Hrs				Boiling Point: °C	
100°C Heat Test: % Loss, 1st 48 Hrs 2.10 % Loss, 2nd 48 Hrs 2.20 Explosion in 100 Hrs None				Refractive Index, n _D ²⁰ n _D ²⁵ n _D ³⁰	
Flammability Index:				Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 7.6 120°C 135°C 150°C	
Hygroscopicity: % 30°C, 90% RH 0.04				200 Gram Bomb Sand Test: Sand gm 47.5 Black powder fuse 45.6	
Volatility: 50°C, 30 months Unaffected				Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.10	
				Ballistic Mortar, % TNT: (a) 97	
				Trauzl Test, % TNT:	
				Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
				Detonation Rate: Confinement Condition Pressed Charge Diameter, in. Density, gm/cc 0.9 1.5 1.6 Rate, meters/second 4400 6600 6900	

*Until it is established which picramic acid (melting point 169°C) isomer is involved (Ref: J Chem Soc, 2082, August 1949).

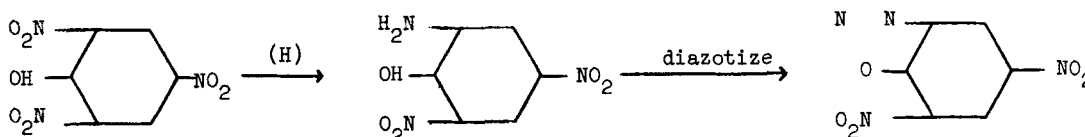
Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="text-align: right;">Glass Cones Steel Cones</div> Hole Volume Hole Depth
	Color: Yellow needles
	Principal Uses: Percussion caps
	Method of Loading: Pressed
	Loading Density: gm/cc Apparent 0.27 At 3000 psi 1.14
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Under water Hazard Class (Quantity-Distance) Class 9 Compatibility Group Exudation None
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	<u>Solubility:</u> Soluble in nitroglycerin, nitrobenzene, aniline, pyridine, concentrated hydrochloric acid, and in most common organic solvents. <u>Heat of:</u> <div style="text-align: right;">Combustion, cal/gm 3243 Explosion, cal/gm 820 Gas Volume, cc/gm 865</div>
	Sensitivity to Electrostatic Discharge, Joules: (b) 0.012

Solubility: gm/100 gm of the following substances: (c)

Solubility at 50°C

<u>Solvent</u>	<u>g</u>
Ethyl acetate	2.45
Methanol	1.25
Ethanol	2.43
Ethylenedichloride	0.79
Carbon tetrachloride	trace
Chloroform	0.11
Benzene	0.23
Toluene	0.15
Petroleum ether	Insoluble (at 20°C)
Ethyl ether	0.08 (30°C)
Carbon disulfide	trace (30°C)

Preparation: (Chemistry of Powder and Explosives, Davis)



Ten gm of picramic acid is suspended in 120 cc of 5% hydrochloric acid, and under efficient agitation at about 0°C. 3.6 gm sodium nitrite in 10 cc water is dumped into the suspension. Stirring is continued for 20 minutes, the product filtered off and washed thoroughly with ice water. The dark brown product, if dissolved in acetone and precipitated in water, turns brilliant yellow.

Origin:

Discovered by Griess in 1858 (Annalen 106, 123; 113, 205 (1860) and studied extensively by L. V. Clark (Ind Eng Chem 25, 663 (1933)). Developed for commercial use in 1928. This compound was patented in the United States by Professor William M. Dane.

Destruction by Chemical Decomposition:

Diazodinitrophenol is decomposed by adding the water-wet material to 100 times its weight of 10% sodium hydroxide. Nitrogen gas is evolved.

References: 18

(a) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.

(b) F. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by

¹⁸See footnote 1, page 10.

Diazodinitrophenol

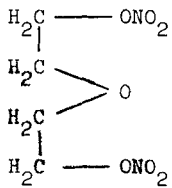
Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.

(c) L. V. Clark, "Diazodinitrophenol, A Detonating Explosive," Ind Eng Chem 25, 663 (1933).

Seidell, Solubilities of Inorganic and Organic Compounds, Van Nostrand and Co., N. Y.

(d) Also see the following Picatinny Arsenal Technical Reports on Diazodinitrophenol:

<u>0</u>	<u>2</u>	<u>4</u>	<u>5</u>	<u>7</u>	<u>8</u>	<u>9</u>
150	1352	34	355	827	318	2179
610		214			1838	
2120						

Composition: %			Molecular Weight: (C ₄ H ₈ N ₂ O ₇) 196		
C	24.5		Oxygen Balance:		
H	4.1		CO ₂ %	-41	
N	14.3		CO %	- 8	
O	57.1				
C/H Ratio 0.143			Density: gm/cc Liquid 1.38		
Impact Sensitivity, 2 Kg Wt:			Melting Point: °C 2		
Bureau of Mines Apparatus, cm 100+			Freezing Point: °C		
Sample Wt 20 mg			Boiling Point: °C Decomposes 160		
Picatinny Arsenal Apparatus, in. 9			Refractive Index, n _D ²⁰		
Sample Wt, mg			n _D ²⁵ 1.4498		
			n _D ³⁰		
Friction Pendulum Test:			Vacuum Stability Test:		
Steel Shoe Explodes			cc/40 Hrs, at		
Fiber Shoe			90°C		
			100°C 0.3cc/20 hr/gm		
			120°C		
			135°C		
			150°C		
Rifle Bullet Impact Test: Trials			200 Gram Bomb Sand Test:		
% Explosions			Sand, gm 42.2		
Partials					
Burned					
Unaffected					
Explosion Temperature: °C			Sensitivity to Initiation:		
Seconds, 0.1 (no cap used)			Minimum Detonating Charge, gm		
1			Mercury Fulminate		
5 237			Lead Azide		
10			Tetryl		
15					
20					
75°C International Heat Test:			Ballistic Mortar, % TNT: 90		
% Loss in 48 Hrs			Trauzl Test, % TNT: 77		
			Plate Dent Test:		
100°C Heat Test:			Method		
% Loss, 1st 48 Hrs 4.0			Condition		
% Loss, 2nd 48 Hrs 3.0			Confined		
Explosion in 100 Hrs None			Density, gm/cc		
			Brisance, % TNT		
Flammability Index:			Detonation Rate:		
			Confinement		
Hygroscopicity: %			Condition		
			Charge Diameter, in.		
Volatility: 60°C, mg/cm ² /hr 193			Density, gm/cc 1.38		
			Rate, meters/second 6760		

Booster Sensitivity Test: Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc	Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH , kcal/mol) Temperature Range, °C Phase
Heat of: Combustion, cal/gm 2792 Explosion, cal/gm 841 Gas Volume, cc/gm 796 Formation, cal/gm 2020 Fusion, cal/gm	Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bombs: Plate Thickness, inches 1 1¼ 1½ 1¾
Specific Heat: cal/gm/°C	Bomb Drop Test: T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete: Max Safe Drop, ft 500-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order 1000-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order
Burning Rate: cm/sec	
Thermal Conductivity: cal/sec/cm/°C	
Coefficient of Expansion: Linear, %/°C Volume, %/°C	
Hardness, Mohs' Scale:	
Young's Modulus: E', dynes/cm² E, lb/inch² Density, gm/cc	
Compressive Strength: lb/inch²	
Vapor Pressure: °C mm Mercury 20 0.0036 60 0.130	

Origin:

First prepared and studied by Wm. H. Rinkenbach in 1927 (Ind Eng Chem 19, 925 (1927) and later by Rinkenbach and H. A. Aaronson (Ind Eng Chem 23, 160 (1931)) both of Picatinny Arsenal. Used in propellant compositions by the Germans during World War II.

Destruction by Chemical Decomposition:

DEGN is decomposed by adding it slowly to 10 times its weight of 18% sodium sulfide ($\text{Na}_2\text{S} \cdot 9\text{H}_2\text{O}$). Heat is liberated by this reaction but this is not hazardous if stirring is maintained during the addition of DEGN and continued until solution is complete.

References:¹⁹

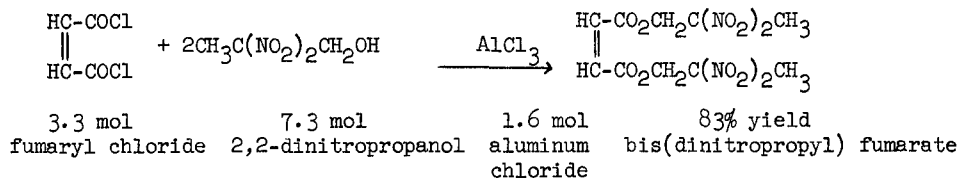
See the following Picatinny Arsenal Technical Reports on DEGN:

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>6</u>	<u>7</u>	<u>9</u>
50	231	72	673	494	346	487	279
180	551	602	1443	1624	1516	1427	579
620	1391	1282			1616	1487	1439
1490	1421	1392			1786	1817	
1990							

¹⁹See footnote 1, page 10.

Composition:		Molecular Weight: $(C_{10}H_{12}N_4O_{12})$		380
%		Oxygen Balance:		
C	31.6	CO ₂ %		-59
H	3.2	CO %		-17
N	14.7	Density: gm/cc		Crystal 1.60
O	50.5	Melting Point: °C		Form I 89
C/H Ratio		Form II		86
Impact Sensitivity, 2 Kg Wt:		Freezing Point: °C		
Bureau of Mines Apparatus, cm	100+	Boiling Point: °C		
Sample Wt 20 mg		Refractive Index, n_{20}^D		
Picatinny Arsenal Apparatus, in.	18	n_{25}^D		
Sample Wt, mg	18	n_{30}^D		
Friction Pendulum Test:		Vacuum Stability Test:		
Steel Shoe	Unaffected	cc/40 Hrs, at		
Fiber Shoe	Unaffected	90°C		----
Rifle Bullet Impact Test:		100°C		0.66
	Trials	120°C		----
	%	135°C		0.91
Explosions		150°C		
Partial		200 Gram Bomb Sand Test:		
Burned		Sand, gm		
Unaffected		Sensitivity to Initiation:		
Explosion Temperature: °C		Minimum Detonating Charge, gm		
Seconds, 0.1 (no cap used)	---	Mercury Fulminate		
1	---	Lead Azide		
4	Smokes 250	Tetryl		
10		Ballistic Mortar, % TNT:		
15		Trauzl Test, % TNT:		
20		Plate Dent Test:		
75°C International Heat Test:		Method		
% Loss in 48 Hrs		Condition		
100°C Heat Test:		Confined		
% Loss, 1st 48 Hrs		Density, gm/cc		
% Loss, 2nd 48 Hrs		Brisance, % TNT		
Explosion in 100 Hrs		Detonation Rate:		
Flammability Index:		Confinement		
Hygroscopicity: %		Condition		
Volatility:		Charge Diameter, in.		
		Density, gm/cc		1.49
		Rate, meters/second		6050

<p>Fragmentation Test:</p> <p>90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments: For TNT For Subject HE</p> <p>3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments: For TNT For Subject HE</p> <p>Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc</p>	<p>Shaped Charge Effectiveness, TNT = 100:</p> <p>Glass Cones Steel Cones</p> <p>Hole Volume</p> <p>Hole Depth</p> <hr/> <p>Color: White</p> <hr/> <p>Principal Uses:</p> <hr/> <p>Method of Loading: Cast</p> <hr/> <p>Loading Density: gm/cc 1.50</p> <hr/> <p>Storage:</p> <p>Method Dry</p> <p>Hazard Class (Quantity-Distance)</p> <p>Compatibility Group</p> <p>Exudation None</p>
<p>Blast (Relative to TNT):</p> <p>Air: Peak Pressure Impulse Energy</p> <p>Air, Confined: Impulse</p> <p>Under Water: Peak Pressure Impulse Energy</p> <p>Underground: Peak Pressure Impulse Energy</p>	<p>Heat of:</p> <p>Combustion, cal/gm 3070 (calculated)</p> <p>Detonation, cal/gm 767 (calculated)</p> <p>Viscosity, poises:</p> <p>Temp, 98.9°C 0.586 106.5°C 0.435</p> <p>Liquid Density, gm/cc:</p> <p>Temp, 98.9°C 1.382 106.5°C 1.375</p> <p>Origin:</p> <p>Synthesized in 1952 by M. E. Hill of the U.S. Naval Ordnance Laboratory, White Oak, Maryland.</p>

(a, b) 

Dinitropropanol was mixed with chloroform (1320 milliliters) and the mixture heated to boiling. The distillate was collected in a water separator. At first the distillate was cloudy and this was dried with calcium chloride before being returned to the system. When no more water was collected in the water separator, the mixture was cooled to room temperature and the separator removed. Fumaryl chloride was introduced, followed by the aluminum chloride which was added in four equal portions. Air was blown into the flask for a minute to effect mixing, and the reaction sustained itself without the addition of heat for one hour. Steam was gradually introduced so that the reflux temperature was reached 2-1/2 hours after the beginning of the reaction. After 3 hours of reflux, the hot liquid was poured into a bucket. As cooling took place the slurry was vigorously agitated until it finally set up at room temperature. This material was broken up and mixed with dilute ice cold HCl. The solid product was collected on a sintered funnel, washed with water and with hexane. The crude material was recrystallized from methanol to give a product melting at 86°C (uncorrected), but after storage for several days the melting point was 89°C.

References: 20

- (a) M. E. Hill, Preparation and Properties of 2,2-Dinitropropanol Esters, NAVORD Report No. 2497, 3 July 1952.
- (b) D. L. Kouba and H. D. McNeil, Jr., Hercules Report on High Explosives, Navy Contract NOrd-11280, Task A, 26 May 1954.

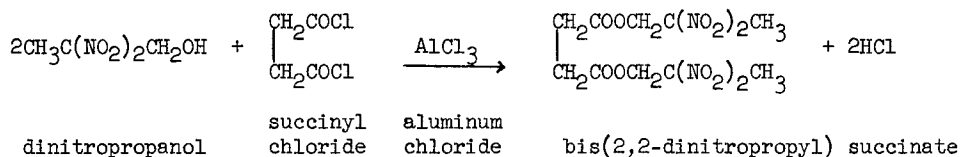
²⁰See footnote 1, page 10.

Composition: % C 31.4 H 3.7 N 14.7 O 50.2 C/H Ratio 0.250 $\begin{array}{c} \text{CH}_2\text{CO}_2\text{CH}_2\text{C}(\text{NO}_2)_2\text{CH}_3 \\ \\ \text{CH}_2\text{CO}_2\text{CH}_2\text{C}(\text{NO}_2)_2\text{CH}_3 \end{array}$	Molecular Weight: (C ₁₀ H ₁₄ N ₄ O ₁₂) 382	
	Oxygen Balance: CO ₂ % -63 CO % -21	
	Density: gm/cc	Crystal 1.51
	Melting Point: °C 86	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	Boiling Point: °C	
	Refractive Index, n _D ²⁰ n _D ²⁵ n _D ³⁰	
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C ---- 100°C 0.10 120°C 135°C 150°C	
Rifle Bullet Impact Test: Trials % Explosions Partial Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm	
Explosion Temperature: °C Seconds, 0.1 (no cap used) --- 1 --- 5 >400 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	
75°C International Heat Test: % Loss in 48 Hrs	Ballistic Mortar, % TNT:	
	Trauzl Test, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Plate Dent Test: Method Condition Confined Density, gm/cc Brinsane, % TNT	
Flammability Index:	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
Hygroscopicity: %		
Volatility:		

<p>Fragmentation Test:</p> <p>90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments: For TNT For Subject HE</p> <p>3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments: For TNT For Subject HE</p>	<p>Shaped Charge Effectiveness, TNT = 100:</p> <p>Glass Cones Steel Cones</p> <p>Hole Volume</p> <p>Hole Depth</p>
<p>Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc</p>	<p>Color: White</p>
<p>Blast (Relative to TNT):</p> <p>Air: Peak Pressure Impulse Energy</p> <p>Air, Confined: Impulse</p> <p>Under Water: Peak Pressure Impulse Energy</p> <p>Underground: Peak Pressure Impulse Energy</p>	<p>Principal Uses:</p>
	<p>Method of Loading: Cast</p>
	<p>Loading Density: gm/cc</p>
	<p>Storage:</p> <p>Method Dry</p> <p>Hazard Class (Quantity-Distance)</p> <p>Compatibility Group</p> <p>Exudation None</p>
	<p><u>Origin:</u></p> <p>Synthesized in 1953 by M. E. Hill of the U.S. Naval Ordnance Laboratory, White Oak, Maryland.</p>

Preparation:

(a)

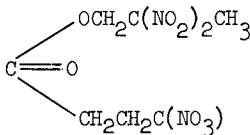


A methylene chloride solution of dinitropropanol (0.02 mol in 15 milliliters) was mixed with 0.01 mol of succinyl chloride. To this solution 0.003 mol of crushed anhydrous aluminum chloride was added. It was necessary to cool the reaction vessel due to the vigorousness of the reaction. After 25 minutes at room temperature the reaction solution was refluxed 1-1/2 hours. Fine needle-like crystals formed upon cooling and adding hexane. The crystals were slurried in dilute hydrochloric acid and on recrystallization from methanol gave a 93% yield of DNPS (melting point 85° to 85.6°C).

References:²¹

- (a) M. E. Hill, Synthesis of New High Explosives, NAVORD Report No. 2965, 1 April 1953.

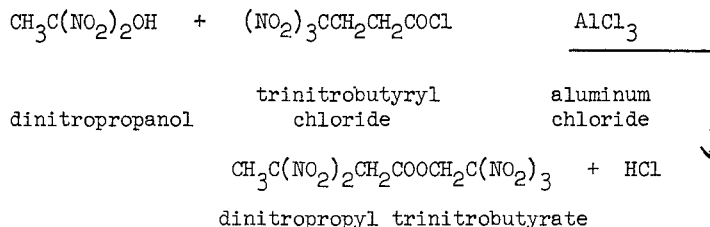
²¹See footnote 1, page 10.

Composition: % C 23.6 H 2.5 N 19.7 O 54.2 C/H Ratio				Molecular Weight: (C ₇ H ₉ N ₅ O ₁₂) 355	
		Oxygen Balance: CO ₂ % -29 CO % +2.3			
		Density: gm/cc Crystal 1.68			
		Melting Point: °C Form I 11 Form II 95 Form III 59			
		Freezing Point: °C			
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg		Boiling Point: °C			
		Refractive Index, n ₂₀ ^D n ₂₅ ^D n ₃₀ ^D			
Friction Pendulum Test: Steel Shoe Fiber Shoe		Vacuum Stability Test: cc/40 Hrs, at 90°C --- 100°C 0.5 120°C 135°C 150°C			
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected		200 Gram Bomb Sand Test: Sand, gm			
Explosion Temperature: °C Seconds, 0.1 (no cap used) --- 1 --- 5 300 10 15 20		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl			
75°C International Heat Test: % Loss in 48 Hrs		Ballistic Mortar, % TNT:			
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs		Treuzl Test, % TNT:			
Flammability Index:		Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT			
Hygroscopicity: %		Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc 1.67 Rate, meters/second 7600			
Volatility:					

<p>Fragmentation Test:</p> <p>90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments: For TNT For Subject HE</p> <p>3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments: For TNT For Subject HE</p> <p>Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc</p>	<p>Shaped Charge Effectiveness, TNT = 100:</p> <p>Glass Cones Steel Cones</p> <p>Hole Volume</p> <p>Hole Depth</p> <hr/> <p>Color: White</p> <hr/> <p>Principal Uses:</p> <hr/> <p>Method of Loading: Cast</p> <hr/> <p>Loading Density: gm/cc 1.67</p> <hr/> <p>Storage:</p> <p>Method Dry</p> <p>Hazard Class (Quantity-Distance)</p> <p>Compatibility Group</p> <p>Exudation None</p>																															
<p>Blast (Relative to TNT):</p> <p>Air: Peak Pressure Impulse Energy</p> <p>Air, Confined: Impulse</p> <p>Under Water: Peak Pressure Impulse Energy</p> <p>Underground: Peak Pressure Impulse Energy</p>	<p>Heat of: (c)</p> <table border="0"> <tr> <td></td> <td></td> <td colspan="2"><u>Solvent</u></td> </tr> <tr> <td>Transition, cal/gm</td> <td></td> <td><u>CCl₄</u></td> <td><u>DMF</u></td> </tr> <tr> <td>I → III</td> <td></td> <td>6.2</td> <td>4.8</td> </tr> <tr> <td>II → I</td> <td></td> <td>-16.6</td> <td>-22.0</td> </tr> </table> <p>Heat of Solution, 30°C:</p> <table border="0"> <tr> <td></td> <td colspan="2"><u>ΔH Solution, cal/gm</u></td> </tr> <tr> <td><u>Material</u></td> <td><u>CCl₄</u></td> <td><u>DMF</u></td> </tr> <tr> <td>Form III</td> <td>29.5</td> <td>8.1</td> </tr> <tr> <td>Form I</td> <td>35.6</td> <td>12.8</td> </tr> <tr> <td>Form II</td> <td>19.1</td> <td>-9.1</td> </tr> </table> <p>Origin:</p> <p>Synthesized in 1952 by M. E. Hill of the U.S. Naval Ordnance Laboratory, White Oak, Maryland.</p>			<u>Solvent</u>		Transition, cal/gm		<u>CCl₄</u>	<u>DMF</u>	I → III		6.2	4.8	II → I		-16.6	-22.0		<u>ΔH Solution, cal/gm</u>		<u>Material</u>	<u>CCl₄</u>	<u>DMF</u>	Form III	29.5	8.1	Form I	35.6	12.8	Form II	19.1	-9.1
		<u>Solvent</u>																														
Transition, cal/gm		<u>CCl₄</u>	<u>DMF</u>																													
I → III		6.2	4.8																													
II → I		-16.6	-22.0																													
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Form III	29.5	8.1																														
Form I	35.6	12.8																														
Form II	19.1	-9.1																														

Preparation:

(a, b)



Dinitropropanol, trinitrobutyryl chloride and aluminum chloride were slowly mixed in carbon tetrachloride at 60°C. This mixture was refluxed at 75°C for two hours. After the reaction was completed, the mixture was cooled and the crystalline product separated and purified. Water in the dinitropropanol was removed by azeotropic distillation before the acid chloride was added. The purified product had a melting point of 95° to 96°C.

Crystallographic Data:

(c)

Three distinct crystallographic modifications of DNPTB have been observed. These polymorphs have been characterized by means of X-ray diffraction and microscopic observation. Form I crystallizes from solution in carbon tetrachloride, chloroform, acetone, chloroform-hexane, acetone-water, or methanol-water at room temperature. Prolonged standing of Form I at room temperature under the mother liquor promotes a transition to Form II. Upon solidification of molten DNPTB, Form II is always observed.

Linear Rate of Transformation of Form II to Form I (c)

Temperature, °C	Average Rate, sq inch/hour	Standard Deviation	Average Rate, mm/hour
15	0.347	0.036	0.012
20	0.435	0.025	0.128
25	0.452	0.048	0.133
30	0.475	0.049	0.140
35	0.253	0.037	0.075

Both Forms I and III gave very erratic sensitivity values. The high temperature polymorph, Form II of DNPTB, gave consistent sensitivity values.

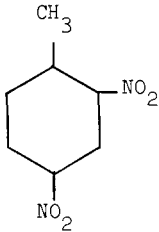
References:²²

(a) M. E. Hill, Preparation and Properties of 2,2-Dinitropropanol Esters, NAVORD Report No. 2497, 3 July 1952.

(b) W. B. Hewson, Hercules Report on High Explosives, Navy Contract NOrd-11280, Task A, 18 October 1954.

(c) J. R. Holden and J. Wenograd, Physical Properties of an Experimental Castable Explosive 2,2-Dinitropropyl 2,4,4-Trinitrobutyrate DNPTB, NAVORD Report No. 4427, 11 December 1956.

²²See footnote 1, page 10.

Composition: % C 46.3 H 3.3 N 15.4 O 35.0 C/H Ratio 0.579				Molecular Weight: ($C_7H_6N_2O_4$) 1.82
		Oxygen Balance: CO ₂ % -114 CO % - 53		
		Density: gm/cc 1.521		
		Melting Point: °C 71		
		Freezing Point: °C		
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg		Boiling Point: °C Decomposes 300		
		Refractive Index, n_{20}^D n_{25}^D n_{30}^D		
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected		Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 0.04 135°C 150°C		
Rifle Bullet Impact Test: Trials Explosions % 0 Partial 0 Burned 0 Unaffected 100		200 Gram Bomb Sand Test: Sand, gm 19.3		
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 310 10 15 20		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.25		
		Ballistic Mortar, % TNT: (a) 71		
		Trauzl Test, % TNT: (b) 64		
75°C International Heat Test: % Loss in 48 Hrs		Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT		
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs		Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second		
Flammability Index:				
Hygroscopicity: % 25°C, 100% RH 0.00				
Volatility:				

Preparation:

See TNT.

Solubility: gm/100 gm of the following substances:

<u>30%</u> <u>Ethyl Alcohol</u>		<u>Nitroglycerin</u>		<u>Water</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
25	0.16	20	30	22	0.027
35	0.29			50	0.037
45	0.49			100	0.254
55	0.77				
60	1.03				

Solubility at 15°C, in:

<u>Solvent</u>	<u>%</u>	<u>Solvent</u>	<u>%</u>
CHCl ₃	65.076	C ₂ H ₅ OH (absolute)	3.039
CCl ₄	2.431	Ether (absolute)	9.422
C ₆ H ₆	60.644	Acetone	81.901
Toluol	45.470	Ethyl acetate	57.929
CH ₃ OH	5.014	CS ₂	2.306
C ₂ H ₅ OH (96%)	1.916	Pyridine	76.810

Origin:

Occurs as 75% of the products obtained on the nitration of toluene, the remaining 25% being mainly 2,6-DNT and other isomers of DNT. Also occurs as an impurity in crude TNT obtained by standard manufacturing process. Used in explosive mixtures at least since 1931.

References:²³

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) A. H. Blatt, Compilation of Data on Organic Explosives, OSRD Report No. 2014, 29 February 1944.

(c) Report AC-2861.

(d) Also see the following Picatinny Arsenal Technical Reports on DNT:

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
810	1351	72	43	394	1615	186	97	768	69
1830	1501	372	233	804	2125	1556	817	938	149
	1651	922	343	1044		1816	837	1538	249
	1781	1142	673	1084		1896			279
	1821	1672	1023	1094					779
	2031	1692	1663	1164					1749
	2221		1743	1324					
			2013	1464					
				1524					
				1674					
				1754					
				2094					

²³See footnote 1, page 10.

Composition: % C 21.7 H 2.9 N 15.2 O 60.2 <div style="text-align: center;"> $\begin{array}{c} \text{ONO}_2 \qquad \qquad \text{ONO}_2 \\ \qquad \qquad \qquad \\ \text{CH}_2 \qquad \qquad \text{CH}_2 \\ \qquad \qquad \qquad \\ \text{ON}_2\text{OCH}_2\text{C}-\text{CH}_2-\text{O}-\text{CH}_2-\text{CCH}_2\text{ONO}_2 \\ \qquad \qquad \qquad \\ \text{CH}_2 \qquad \qquad \text{CH}_2 \\ \qquad \qquad \qquad \\ \text{ONO}_2 \qquad \qquad \text{ONO}_2 \end{array}$ </div> C/H Ratio 0.154		Molecular Weight: ($\text{C}_{10}\text{H}_{16}\text{N}_6\text{O}_{19}$) 554	
		Oxygen Balance: CO ₂ % -26 CO % + 3	
		Density: gm/cc Crystal 1.63	
		Melting Point: °C 73.7	
		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 14 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 4 Sample Wt, mg 10		Boiling Point: °C	
		Refractive Index, n_{20}^D n_{25}^D n_{30}^D	
Friction Pendulum Test: Steel Shoe Explodes Fiber Shoe Unaffected		Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 3.7 120°C 11+ 135°C 150°C	
Rifle Bullet Impact Test: Trials % Explosions Partial Burned Unaffected		200 Gram Bomb Sand Test: Sand, gm 57.4	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 300 5 Explodes 255 10 15 20		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	
		Ballistic Mortar, % TNT: (a) 142	
		Trauzl Test, % TNT: (b) 128	
75°C International Heat Test: % Loss in 48 Hrs		Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
100°C Heat Test: % Loss, 1st 48 Hrs 0.11 % Loss, 2nd 48 Hrs 0.10 Explosion in 100 Hrs None		Detonation Rate: (c) Confinement Copper tube Condition Pressed Charge Diameter, in. 0.39 Density, gm/cc 1.59 Rate, meters/second 7410	
Flammability Index:			
Hygroscopicity: % 0.03			
Volatility:			

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: White Principal Uses: Ingredient of priming compositions
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Method of Loading: Pressed Loading Density: gm/cc At 3000 to 4000 psi 1.59
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Exudation Preparation: (Chemistry of Powder and Explosives, Davis) $ \begin{array}{ccc} 2(\text{HO}-\text{CH}_2)_4\text{C} & \xrightarrow{\text{Dehydration}} & \\ (\text{HO}-\text{CH}_2)_3\text{C}-\text{O}-\text{C}(\text{CH}_2-\text{OH})_3 & \longrightarrow & \\ (\text{O}_2\text{NO}-\text{CH}_2)_3\text{C}-\text{O}-\text{C}(\text{CH}_2-\text{ONO}_2)_3 & & \end{array} $ Dipentaerythritol Hexanitrate is procured in the pure state (melting point 72°C) by fractional crystallization of crude PETN from moist acetone. Origin: Formed as an impurity in the preparation of PETN. Properties first described by W. Frederick and W. Brün in 1930 (Berichte 63, 2861 (1930); Z. ges. Schiess-Sprengstoffw 27, 73-6, 125-7, 156-8 (1932)). Heat of: Combustion, cal/gm 2260

References:²⁴

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) A. Stettbacher, Die Schiess und Sprengstoffe, Leipsiz, p. 363.
- (c) T. L. Davis, The Chemistry of Powder and Explosives, John Wiley and Sons, Inc., New York (1943) pp. 218-283.
- (d) S. Livingston, Characteristics of Explosives HMX and DPEHN, PATR No. 1561, 6 September 1945.

²⁴See footnote 1, page 10.

Composition: 99.5/0.5 RDX/1-MA dye* 17.5 % TNT 67.8 Tripentaerythritol 8.6 68/32 Vistac No 1/DOS binders** 4.1 Cellulose acetate, LH-1 2.0 *RDX, Class E; 1-MA is 96% pure 1-methylamino-anthraquinone. **Vistac No 1 is low MW polybutene; DOS is dioctylsebacate. C/H Ratio	Molecular Weight:	
	Oxygen Balance: CO ₂ % CO %	
	Density: gm/cc	Loading 0.9
	Melting Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 22 Sample Wt, mg 19	Freezing Point: °C	
	Boiling Point: °C	
	Refractive Index, n_{20}^D n_{25}^D n_{30}^D	
	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 0.90 135°C 150°C	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	200 Gram Bomb Sand Test: Sand, gm 40.5	
Rifle Bullet Impact Test: Trials % Explosions Partial Burned Unaffected	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.15	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Ignites 480 10 15 20	Ballistic Mortar, % TNT: 92	
75°C International Heat Test: % Loss in 48 Hrs	Trauzl Test, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
Flammability Index:	Detonation Rate: Confinement None Condition Hand tamped Charge Diameter, in. 1.25 Density, gm/cc 0.9 Rate, meters/second 4397; or 14400 ft/sec	
Hygroscopicity: % 0.31 71°C, 95% RH, 30 days Satisfactory		
Volatility:		

<p>Fragmentation Test:</p> <p>90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments: For TNT For Subject HE</p> <p>3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments: For TNT For Subject HE</p>	<p>Shaped Charge Effectiveness, TNT = 100:</p> <p>Glass Cones Steel Cones</p> <p>Hole Volume</p> <p>Hole Depth</p>
<p>Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc</p>	<p>Color: Pink</p>
<p>Blast (Relative to TNT):</p> <p>Air: Peak Pressure Impulse Energy</p> <p>Air, Confined: Impulse</p> <p>Under Water: Peak Pressure Impulse Energy</p> <p>Underground: Peak Pressure Impulse Energy</p>	<p>Principal Uses: Excavation, demolition, and cratering</p>
	<p>Method of Loading: Hall Packer machine loaded</p>
	<p>Loading Density: gm/cc 0.9 Tamped cartridge 1-1/2" diameter, 8" long</p>
	<p>Storage:</p> <p>Method Dry</p> <p>Hazard Class (Quantity-Distance) Class 9</p> <p>Compatibility Group Group A</p> <p>Exudation</p>
	<p>Sensitivity to Initiation: Stick dry, No. 6 Electric cap Positive Stick dry, Corps of Engineers Positive Stick wet, Corps of Engineers Positive</p> <p>Air Gap Propagation: Max distance will, inch 2-1/2 min distance will not, inch 3</p> <p>Stick Water Immersion: Weight gain, % 9-16</p> <p>Heat of: Explosion, cal/gm 625 Gas Volume, cc/gm 611</p> <p>Cold Storage: Plastic to -65°F</p> <p>Low Temperature Usage: -65°F, 1 day, M2 cap crimper Satisfactory</p>

Preparation:

To date this dynamite has been prepared on a laboratory scale, the details of which are classified. It has been shown, however, to be machine loadable on a Hall packing machine.

Origin:

Nobel invented the original dynamite in 1866 and gave the name dynamite to mixtures of nitroglycerin and kieselguhr. The strength of a dynamite was indicated by the percentage of NG in the mixture. Later oxidants and combustibles were substituted for the kieselguhr, and ammonium nitrate and/or nitrostarch replaced the NG, bringing into existence new types of dynamites. World War II military operations required special demolition and cratering explosives free from the objectionable characteristics of NG and many "dynamite substitutes" were developed for specific applications. The subject low velocity dynamite was developed in 1956 by Picatinny Arsenal (Ref a).

References: ²⁵

(a) H. W. Voigt, Development of Low-Velocity Military Explosives Equivalent to Commercial Dynamites, PA Technical Report 2374, March 1957.

(b) Also see the following Picatinny Arsenal Technical Reports on Dynamites:

<u>0</u>	<u>1</u>	<u>2</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
1260	1381	782	864	1285	1416	507	848	1819
1360	1611	1532	1464		1436	957	1828	
1720					1506			
1760					2056			

²⁵See footnote 1, page 10.

Composition: % RDX 75 TNT 15 Starch 5 SAE No. 10 Oil 4 Vistanex oil gel* 1 *80/15/5, SAE No. 10 weight oil/Vistanex B-120XC/Navy D2 wax. C/H Ratio	Molecular Weight:	
	Oxygen Balance: CO ₂ % -51 CO %	
	Density: gm/cc	Loading 1.1
	Melting Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm >100 Sample Wt 20 mg 18 Picatinny Arsenal Apparatus, in. 25 Sample Wt, mg	Freezing Point: °C	
	Nitroglycerin Equivalent, % 60	
	Refractive Index, n_{20}^D n_{25}^D n_{30}^D	
	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.80 120°C 0.94 135°C 150°C	
Friction Pendulum Test: Steel Shoe Crackles Fiber Shoe Unaffected	200 Gram Bomb Sand Test: Sand, gm 52.6	
	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.10	
	Ballistic Mortar, % TNT: 122	
	Trauzl Test, % TNT:	
Rifle Bullet Impact Test: Trials % Explosions 0 Partial 0 Burned 10 Unaffected 90	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
	Detonation Rate: Confinement None Condition Machine tamped Charge Diameter, in. 1.50 Density, gm/cc 1.1 Rate, meters/second 6000-6600; or 20,000 ft/sec	
	Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 10 15 20	
	75°C International Heat Test: % Loss in 48 Hrs	
100°C Heat Test: % Loss, 1st 48 Hrs 0.62 % Loss, 2nd 48 Hrs 0.12 Explosion in 100 Hrs None	Flammability Index:	
	Hygroscopicity: % 71°C, 95% RH, 30 days Satisfactory	
	Volatility:	

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div> Glass Cones Steel Cones Hole Volume Hole Depth </div>
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Color: Buff Principal Uses: Excavation, demolition, and cratering Method of Loading: Hall Packer machine loaded Loading Density: gm/cc 1.1 Cartridge 1-1/2" diameter, 8" long
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Storage: <div> Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group A Exudation </div> Sensitivity to Initiation: Stick dry, No. 6 Electric cap Positive Stick dry, Corps of Engineers Positive Stick wet, Corps of Engineers > 50% Positive Air Gap Propagation: Max distance will, inch 1 Min distance will not, inch 2-1/2 Quarry Performance: 4 tons rock/ton explosive Stick Water Immersion: Weight gain, % 25-27 Heat of: Explosion, cal/gm 935 Gas Volume, cc/gm 945 Cold Storage: Plastic to -70°F Low Temperature Usage: -65°F, 1 day, M2 cap crimper Satisfactory

Preparation:

Manufactured on standard dynamite line and packaged on a Hall packing machine. Details of handling materials and techniques of manufacture are classified.

Origin:

Military forces frequently require excavation, demolition, and cratering operations for which standard high explosives are unsuitable. Commercial blasting explosives, except black powder, are called dynamites although they may contain no nitroglycerin. The subject dynamite substitute was developed in 1952 by the Hercules Powder Company (Ref a).

References:²⁶

(a) W. R. Baldwin, Jr., Blasting Explosives (Dynamite Substitute), Hercules Powder Company Formal Progress Report, RI 2086, 15 August 1952, Army Contract DA-36-034-ORD-110.

(b) H. W. Voigt, Development of Low-Velocity Military Explosives Equivalent to Commercial Dynamites, PA Technical Report No. 2374, March 1957.

²⁶See footnote 1, page 10.

AMCP 706-177

EC Blank Fire

Composition: % Nitrocellulose, 13.25% N 80 Barium Nitrate 8 Potassium Nitrate 8 Starch 3 Diphenylamine 0.75 Aurine 0.25 C/H Ratio	Molecular Weight: Approximately 503	
	Oxygen Balance: CO ₂ % +5 CO % -25	
	Density: gm/cc	
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 19 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg 20	Boiling Point: °C	
	Refractive Index, n_D^{20} n_D^{25} n_D^{30}	
	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C	
Friction Pendulum Test: Steel Shoe Snaps Fiber Shoe	200 Gram Bomb Sand Test: Sand, gm 46.8	
Rifle Bullet Impact Test: Trials % Explosions Partial Burned Unaffected	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.22 Lead Azide Tetryl	
	Ballistic Mortar, % TNT:	
	Trauzl Test, % TNT:	
	Plate Dent Test: Method Condition Confined Density, gm/cc Brissance, % TNT	
	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 200 10 15 20		
75°C International Heat Test: % Loss in 48 Hrs 1.8		
100°C Heat Test: % Loss, 1st 48 Hrs 2.0 % Loss, 2nd 48 Hrs 0.2 Explosion in 100 Hrs None		
Flammability Index:		
Hygroscopicity: % 30°C, 90% RH 6.2		
Volatility:		

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <table> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>		Glass Cones	Steel Cones	Hole Volume			Hole Depth		
	Glass Cones	Steel Cones								
Hole Volume										
Hole Depth										
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Color: Principal Uses: Grenades; caliber .30 blank									
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Method of Loading: Loose Loading Density: gm/cc 0.40 Storage: <table> <tr> <td>Method</td> <td>Wet</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td>Class 0</td> </tr> <tr> <td>Compatibility Group</td> <td>Group J</td> </tr> <tr> <td>Exudation</td> <td></td> </tr> </table> <p>Preparation: EC Blank Fire is a partially colloided propellant manufactured by a process using either acetone and ethanol or a mixture of butyl acetate and benzene to gelatinize only a part of the nitrocellulose. The process is controlled so that the product passes through a No. 12 sieve and is retained on a No. 50 sieve.</p> <p>Origin: Invented in 1882 as bulk sporting (smokeless) powder by W. F. Reid and D. Johnson at the Explosive Company (whence the name "EC") in England (British Patent 619).</p>	Method	Wet	Hazard Class (Quantity-Distance)	Class 0	Compatibility Group	Group J	Exudation		
Method	Wet									
Hazard Class (Quantity-Distance)	Class 0									
Compatibility Group	Group J									
Exudation										
References: ²⁷ (a) See the following Picatinny Arsenal Technical Reports on EC Blank Fire: 891, 901, 372, 512, 822, 233, 1373, 854, 65, 667, 817, 69, 579 and 1399.	120°C Heat Test: <table> <tr> <td></td> <td>Minutes</td> </tr> <tr> <td>Salmon Pink</td> <td>150</td> </tr> <tr> <td>Red Fumes</td> <td>300+</td> </tr> <tr> <td>Explodes</td> <td>300+</td> </tr> </table>		Minutes	Salmon Pink	150	Red Fumes	300+	Explodes	300+	
	Minutes									
Salmon Pink	150									
Red Fumes	300+									
Explodes	300+									

²⁷See footnote 1, page 10.

Composition: % Haleite (Ethylene Dinitramine) 55 TNT 45 C/H Ratio	Molecular Weight: 178 Oxygen Balance: CO ₂ % -51 CO % -17 Density: gm/cc Cast 1.62 Melting Point: °C Eutectic 80 Freezing Point: °C Boiling Point: °C Refractive Index, n _D ²⁰ n _D ²⁵ n _D ³⁰
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 95 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg 20	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 1.0 120°C 11+ 135°C 150°C
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	200 Gram Bomb Sand Test: Sand, gm 49.4
Rifle Bullet Impact Test: Trials % Explosions 0 Partials 0 Burned 7 Unaffected 93	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.22* Lead Azide 0.26* Tetryl *Alternative initiating charges.
Explosion Temperature: * °C Seconds, 0.1 (no cap used) 435 1 248 5 Decomposes 190 10 183 15 176 20 168 *Composition Haleite/TNT, 60/40.	Ballistic Mortar, % TNT: (a) 119
75°C International Heat Test: % Loss in 48 Hrs	Trauzl Test, % TNT: (b) 120
100°C Heat Test: % Loss, 1st 48 Hrs 0.2 % Loss, 2nd 48 Hrs 0.1 Explosion in 100 Hrs None	Plate Dent Test: 52/48 Method B Condition Cast Confined No Density, gm/cc 1.62 Brisance, % TNT 112
Flammability Index: Will not continue to burn	Detonation Rate: Confinement None Condition Cast Charge Diameter, in. 1.0 Density, gm/cc 1.63 Rate, meters/second 7340
Hygroscopicity: % None	
Volatility:	

Fragmentation Test:			Shaped Charge Effectiveness, TNT = 100: 50/50											
90 mm HE, M71 Projectile, Lot WC-91:			<table><tr><td></td><td>Glass Cones</td><td>Steel Cones</td></tr><tr><td>Hole Volume</td><td>126</td><td>123</td></tr><tr><td>Hole Depth</td><td>117</td><td>121</td></tr></table>				Glass Cones	Steel Cones	Hole Volume	126	123	Hole Depth	117	121
	Glass Cones	Steel Cones												
Hole Volume	126	123												
Hole Depth	117	121												
Density, gm/cc	1.56	1.62	Color: Yellow											
Charge Wt, lb	2.065	2.092	Principal Uses: Projectiles, bombs; special ammunition components											
Total No. of Fragments:			Method of Loading: Cast											
For TNT	703	703	Loading Density: gm/cc 1.65											
For Subject HE	842	902	Storage:											
3 inch HE, M42A1 Projectile, Lot KC-5:			Method Dry											
Density, gm/cc		1.60	Hazard Class (Quantity-Distance) Class 9											
Charge Wt, lb		0.845	Compatibility Group Group I											
Total No. of Fragments:			Exudation Does not exude at 65°C											
For TNT		514	Eutectic Temperature, °C:											
For Subject HE		536	gm Haleite/100 gm TNT											
Fragment Velocity: ft/sec			79.8°C 0.48											
At 9 ft		2730	95.0°C 1.12											
At 25½ ft		2430	Compatibility with Metals:											
Density, gm/cc		1.62	Dry: Brass, aluminum, stainless steel, mild steel, mild steel coated with acid-proof black paint, and mild steel plated with cadmium or nickel are unaffected. Copper, magnesium, magnesium-aluminum alloy and mild steel plated with copper or zinc are slightly affected.											
Blast (Relative to TNT): (d, e)			Wet: Copper, brass, magnesium, magnesium-aluminum alloy, mild steel, mild steel coated with acid-proof black paint and mild steel plated with copper, cadmium, nickel or zinc are heavily attacked. Aluminum is slightly affected and stainless steel is unaffected.											
Air:														
Peak Pressure		108												
Impulse		110												
Energy		108												
Air, Confined:														
Impulse														
Under Water:														
Peak Pressure		--												
Impulse		--												
Energy		113												
Underground:														
Peak Pressure														
Impulse														
Energy														
Booster Sensitivity Test: (d)														
Condition		Cast												
Tetryl, gm		100												
Wax, in. for 50% Detonation		1.28												
Density, gm/cc		1.62												

Preparation:

Wet Haleite is added slowly to molton TNT heated at about 100°C in a steam jacketed melting kettle equipped with a stirrer. Heating and stirring are continued until all moisture is evaporated. Loading is done by pouring the mixture cooled to 85°C.

Origin:

Mixtures of Haleite (EDNA) and TNT, designated Ednatol, were developed at Picatinny Arsenal just prior to World War II.

References:²⁸

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) Philip C. Keenan and Dorothy C. Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.

(c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(d) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Teteryl in Boosters, NOL Memo 10,303, 15 June 1949.

(e) W. R. Tomlinson, Jr., Blast Effects of Bomb Explosives, PA Tech Div Lecture, 9 April 1948.

(f) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Sec III, Variation of Cavity Effect with Composition, NDRC Contract W-672-ORD-5723.

(g) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Final Report, 18 September 1943, NDRC Contract W-672-ORD-5723.

(h) Also see the following Picatinny Arsenal Technical Reports on Ednatol:

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
1290	1291	1162	1193	1294	1325	1796	1457	1198	1279
1400	1451	1372	1363	1434	1395		1477	1388	1469
1420	1651	1482	1493		1885		1737	1838	
1530							1797		

²⁸See footnote 1, page 10.

Composition: % C 25.6 H 2.6 N 17.1 O 54.7 C/H Ratio 0.235	Molecular Weight: (C ₁₀ H ₁₂ N ₆ O ₁₆) 468	
	Oxygen Balance: CO ₂ % -34 CO % 0	
	Density: gm/cc Crystal 1.63	
	Melting Point: °C 96	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	Boiling Point: °C	
	Refractive Index, n ₂₀ ^D n ₂₅ ^D n ₃₀ ^D	
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C	
Rifle Bullet Impact Test: Trials % Explosions Partial Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm	
Explosion Temperature: °C Seconds, 0.1 (no cap used) --- 1 --- 5 50% point 230 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	
	Ballistic Mortar, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs	Trauzl Test, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc 1.63 Rate, meters/second 7340	
Flammability Index:		
Hygroscopicity: %		
Volatility:		

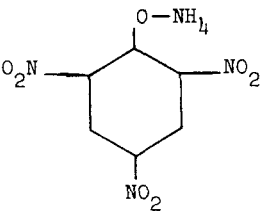
Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Color:
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Principal Uses: Casting medium for HE compounds
	Method of Loading: Cast
	Loading Density: gm/cc 1.60
	Storage: Method Dry Hazard Class (Quantity-Distance) Compatibility Group Exudation None
	Preparation: (a) By the addition of nitroform to ethylene glycol diacrylate. As the method of preparation often leads to products difficult to purify, a preparation from ethylene glycol and pure trinitrobutyric acid is in process. Origin: First synthesized in 1951 by the U.S. Rubber Company, Research and Development General Laboratories, Passaic, New Jersey. Viscosity, poises: <div style="display: flex; justify-content: space-around;"> <div>Temp, 98.9°C 106.5°C</div> <div>0.246 0.193</div> </div> Liquid Density, gm/cc: <div style="display: flex; justify-content: space-around;"> <div>Temp, 98.9°C 106.5°C</div> <div>1.467 1.459</div> </div>

References:²⁹

(a) U. S. Rubber Company Progress Report No. 14, Navy Contract NOrd-10129, 1 February 1951 to 1 May 1951.

(b) U. S. Naval Ordnance Laboratory, Silver Spring, Maryland, Letter from Dr. O. H. Johnson to Commanding Officer, Picatinny Arsenal, 8 April 1955 (ORDBB 471.86/44-3, Registry No. 39815); and NOL Letter from Dr. D. V. Sickman to Commanding Officer, Picatinny Arsenal, 29 November 1955 (ORDBB 471.86/159-1; Serial No. 02894).

²⁹See footnote 1, page 10.

Composition: % C 29.3 H 2.4 N 22.7 O 45.6 C/H Ratio 0.317		Molecular Weight: ($C_6H_6N_4O_7$) 246	
		Oxygen Balance: CO ₂ % -52 CO % -13	
		Density: gm/cc Crystal 1.72	
		Melting Point: °C Decomposes 265	
		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 17 Sample Wt, mg 18		Boiling Point: °C	
		Refractive Index, n_{20}^D a _o 1.508 b _o 1.870 c _o 1.907	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected		Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.2 120°C 0.4 135°C 150°C 0.4	
Rifle Bullet Impact Test: Trials Explosions % 0 Partial 0 Burned 30 Unaffected 70		200 Gram Bomb Sand Test: Sand, gm 39.5	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 405 1 367 5 Decomposes 318 10 314 15 299 20 295		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.06	
		Ballistic Mortar, % TNT: (a) 99	
75°C International Heat Test: % Loss in 48 Hrs		Trauzl Test, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs 0.1 % Loss, 2nd 48 Hrs 0.1 Explosion in 100 Hrs None		Plate Dent Test: Method A Condition Pressed Confined Yes Density, gm/cc 1.50 Brisance, % TNT 91	
Flammability Index:		Detonation Rate: Confinement None Condition Pressed Charge Diameter, in. 1.0 Density, gm/cc 1.55 Rate, meters/second 6850	
Hygroscopicity: % 100% RH 0.1			
Volatility:			

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc 1.50 Charge Wt, lb 1.94 Total No. of Fragments: For TNT 703 For Subject HE 649 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc 1.55 Charge Wt, lb 0.82 Total No. of Fragments: For TNT 514 For Subject HE 508	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones Hole Volume Hole Depth Color: Yellow-orange Principal Uses: AP projectiles and bombs Method of Loading: Pressed
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Loading Density: gm/cc psi x 10³ 3 5 10 12 15 20 1.33 1.41 1.47 1.49 1.51 1.53
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation None at 65°C Sensitivity to Electrostatic Discharge, Joules: (d) <u>Through 100 Mesh:</u> Confined 6.0 Unconfined 0.025 Booster Sensitivity Test: (c) Condition Pressed Tetryl, gm 100 Wax, in. for 50% Detonation 1.27 Density, gm/cc 1.54 Heat of: Combustion, cal/gm 2890 Explosion, cal/gm 800 Formation, cal/gm 395

Preparation:

Explosive D is manufactured by suspending picric acid in hot water and neutralizing it with gaseous or liquid ammonia. As the picrate is formed, it goes into solution; on cooling, it precipitates. An excess of ammonia leads to formation of the red form of ammonium picrate. This should be avoided. The separated crystals are washed with cold water and dried.

Effect of Storage on Sand Test Values:

		<u>Minimum Detonating Charge</u>		
<u>Years</u>	<u>Storage °C</u>	<u>Mercury Fulminate (gm)</u>	<u>Tetryl (gm)</u>	<u>Sand Crushed (gm)</u>
0			0.06	23
3.5	50	0.25		23
2 *	Normal		0.03	23
4 *	Normal		0.04	23
2 **	50	0.24		23

* After 3.5 years at 50°C.

** After 3.5 years at 50°C and 2 years at magazine temperature.

Solubility: gm/100 gm (%), of: (e)

<u>Water</u>		<u>Alcohol</u>		<u>Ethyl Acetate</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
20	1.1	0	0.515	0	0.290
100	75	10	0.690	10	0.300
		30	1.050	30	0.380
		50	1.890	50	0.450
		80	3.620	80	0.560

Origin:

First prepared by Marchand in 1841 and used by Brugere in admixture with potassium nitrate as a propellant in 1869. Used as a high explosive after 1900.

Destruction by Chemical Decomposition:

Explosive D (ammonium picrate) is decomposed by dissolving in 30 times its weight of a solution made from 1 part of sodium sulfide ($\text{Na}_2\text{S} \cdot 9\text{H}_2\text{O}$) in 6 parts of water.

References:³⁰

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

³⁰See footnote 1, page 10.

(b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(c) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Teteryl in Boosters, NOL Memo 10,303, 15 June 1949.

(d) F. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.

(e) Various sources in the open literature.

(f) Also see the following Picatinny Arsenal Technical Reports on Explosive D:

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
340	1441	132	843	694	65	266	1737	328	1729
870	1651	582		704	425	556	1797	838	1759
1380		1172		874	1585	796		1838	
		1352		1234	1655	986			
		1372		1724	1725	1466			
		1492			1885	1796			
					1895				

<p>Fragmentation Test:</p> <p>90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments: For TNT For Subject HE</p> <p>3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments: For TNT For Subject HE</p>	<p>Shaped Charge Effectiveness, TNT = 100:</p> <p>Glass Cones Steel Cones</p> <p>Hole Volume</p> <p>Hole Depth</p> <p>Color:</p> <p>Principal Uses: Gelatinizer for nitrocellulose</p> <p>Method of Loading:</p> <p>Loading Density: gm/cc</p>
<p>Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc</p>	<p>Storage:</p> <p>Method Liquid</p> <p>Hazard Class (Quantity-Distance) Class 9</p> <p>Compatibility Group</p> <p>Exudation</p>
<p>Blast (Relative to TNT):</p> <p>Air: Peak Pressure Impulse Energy</p> <p>Air, Confined: Impulse</p> <p>Under Water: Peak Pressure Impulse Energy</p> <p>Underground: Peak Pressure Impulse Energy</p>	<p><u>Hydrolysis, % Acid:</u></p> <p>10 days at 22°C 0.021 5 days at 60°C 0.014</p> <p><u>Solubility in Water, gm/100 gm, at:</u></p> <p>25°C < 0.01 60°C < 0.015</p> <p><u>Solubility, gm/100 gm, at 25°C, in:</u></p> <p>Ether ∞ 2:1 Ether:Alcohol ∞ Acetone ∞</p> <p><u>Heat of:</u></p> <p>Combustion, cal/gm 2407</p>

Preparation:

Glycerol monolactate (GML) is prepared by heating a glycerol lactic acid mixture containing 4% excess lactic acid at 116°C for 112 hours with dry air bubbling through the liquid. The product which contains 0.67% free acid is carefully mixed with 6 parts of 40/60 HNO₃/H₂SO₄ maintained at 20°C, stirred for 1 hour, cooled to 5°C, and poured on ice. It is extracted with ether, water-washed, adjusted to pH 7 by shaking with a sodium bicarbonate solution, and again water-washed three times. It is then dried with calcium chloride, filtered and freed of ether by bubbling with air until minimal loss in weight is obtained. The product has a nitrate-nitrogen content of 13.43% (theoretical 14.1% N). Another batch, prepared from GML obtained from glycerol-lactic acid containing 6.5% excess glycerol, had a nitrate-nitrogen content of 14.30%, corresponding to a mixture containing 5.5% nitroglycerin. It is not considered practicable to prepare the pure GLTN.

Origin:

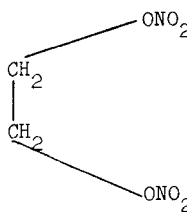
The preparation of a nitrated ester of lactic acid and glycerol, by nitrating a glyceryl lactate with nitric and sulfuric acids, for use in explosives, was reported in 1931 by Charles Stine and Charles Burke (U. S. Patent 1,792,515).

The preparation of glycerol monolactate by heating glycerol with equimolar proportions of a lactic acid ester of an alcohol boiling below 100°C (ethyl lactate) was patented by Richie H. Locke in 1936 (British Patent 456,525 and U. S. Patent 2,087,980).

Reference:³¹

(a) P. F. Macy and A. A. Saffitz, Explosive Plasticizers for Nitrocellulose, PATR No. 1616, 22 July 1946.

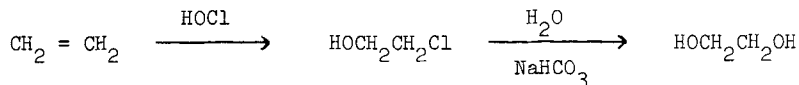
³¹See footnote 1, page 10.

Composition: % C 15.8 H 2.6 N 18.4 O 63.2 C/H Ratio 0.092 <div style="text-align: center;">  </div>	Molecular Weight: ($C_2H_4N_2O_6$) 152	
	Oxygen Balance: CO ₂ % 0.0 CO % 21	
	Density: gm/cc Liquid, 25°C 1.48	
	Melting Point: °C -20	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 4 (1 lb wt); 56 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	Boiling Point: °C	
	Refractive Index, n_{20}^D n_{25}^D 1.4452 n_{30}^D	
	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C	
Friction Pendulum Test: Steel Shoe Fiber Shoe	200 Gram Bomb Sand Test: Sand, gm	
Rifle Bullet Impact Test: Trials % Explosions Partial Burned Unaffected	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	
	Ballistic Mortar, % TNT:	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Explodes 257 10 15 20	Trauzl Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Detonation Rate: Confinement Glass tube Condition Liquid Charge Diameter, in. 10 Density, gm/cc 1.485 Rate, meters/second 7300 and 2050	
Flammability Index:		
Hygroscopicity: % 30°C, 90% RH 0.00		
Volatility:		

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Yellow Principal Uses: Ingredient of nonfreezing dynamite Method of Loading: Loading Density: gm/cc																												
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Liquid Hazard Class (Quantity-Distance) Class 9 Compatibility Group Exudation																												
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Solubility in 1000 cc Water: <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: center;"><u>Temp, °C</u></th><th style="text-align: center;"><u>Grams</u></th></tr> </thead> <tbody> <tr><td style="text-align: center;">15</td><td style="text-align: center;">6.2</td></tr> <tr><td style="text-align: center;">20</td><td style="text-align: center;">6.8</td></tr> <tr><td style="text-align: center;">50</td><td style="text-align: center;">9.2</td></tr> </tbody> </table> Viscosity, centipoises: <table style="width: 100%; border-collapse: collapse;"> <tbody> <tr> <td style="text-align: center;">Temp, 20°C</td><td style="text-align: center;">4.2</td></tr> </tbody> </table> Vapor Pressure: <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: center;"><u>°C</u></th><th style="text-align: center;"><u>mm Mercury</u></th></tr> </thead> <tbody> <tr><td style="text-align: center;">0</td><td style="text-align: center;">0.0044</td></tr> <tr><td style="text-align: center;">20</td><td style="text-align: center;">0.038</td></tr> <tr><td style="text-align: center;">40</td><td style="text-align: center;">0.26</td></tr> <tr><td style="text-align: center;">60</td><td style="text-align: center;">1.3</td></tr> <tr><td style="text-align: center;">80</td><td style="text-align: center;">5.9</td></tr> <tr><td style="text-align: center;">100</td><td style="text-align: center;">22.0</td></tr> </tbody> </table> Heat of: <table style="width: 100%; border-collapse: collapse;"> <tbody> <tr> <td style="text-align: center;">Combustion, cal/gm</td><td style="text-align: center;">1764</td></tr> <tr> <td style="text-align: center;">Formation, cal/gm (b)</td><td style="text-align: center;">366</td></tr> </tbody> </table>	<u>Temp, °C</u>	<u>Grams</u>	15	6.2	20	6.8	50	9.2	Temp, 20°C	4.2	<u>°C</u>	<u>mm Mercury</u>	0	0.0044	20	0.038	40	0.26	60	1.3	80	5.9	100	22.0	Combustion, cal/gm	1764	Formation, cal/gm (b)	366
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100	22.0																												
Combustion, cal/gm	1764																												
Formation, cal/gm (b)	366																												

Preparation:

Glycol dinitrate (ethylene glycol dinitrate, dinitroglycol, nitroglycol, dinitrodimethyleneglycol) may be prepared by nitration of ethylene glycol, $\text{HOCH}_2\text{CH}_2\text{OH}$, with a mixed nitric acid in the same apparatus that is used for the preparation of nitroglycerin. The glycol is prepared by synthesis from ethylene, and ethylene chlorohydrin:

Origin:

Henry was the first to prepare and identify glycol dinitrate (Ber 3, 529 (1870) and Ann chim phys [4] 27, 243 (1872) but Kekulé had previously nitrated ethylene and obtained an unstable oil which he supposed to be glycol nitrate-nitrate. No immediate practical use was made of glycol dinitrate because glycol itself was relatively rare and expensive at the time. It was 1904 before a patent was granted covering the use of GDN as an explosive (DRP 179,789), but it was seven years later before its actual use as an explosive was recorded (Mém poudr 16 (1911) p. 214). The principal physical properties of GDN were determined or recorded by Rinkenbach (Ref b).

References:³²

(a) Ph. Naoum, Nitroglycerin and Nitroglycerin Explosives, translation, E. M. Symmes, The Williams and Wilkins Company, Baltimore (1928), p. 224.

(b) Wm. H. Rinkenbach, "The Properties of Glycol Dinitrate," Ind Eng Chem 18, 1195 (1926).

(c) Wm. H. Rinkenbach, "Glycol Dinitrate in Dynamite Manufacture," Chem Met Eng, 34, 296 (1927).

(d) Wm. H. Rinkenbach, Application of the Vacuum Stability Test to Nitroglycerin and Nitroglycerin Explosives, PATR 1624, 27 August 1946.

³²See footnote 1, page 10.

AMCP 706-177

H-6

Composition: % RDX 45 TNT 30 Aluminum 20 D-2 Wax 5 Calcium Chloride, added 0.5 C/H Ratio	Molecular Weight: 93	
	Oxygen Balance: CO ₂ % -66 CO % -36	
	Density: gm/cc	Cast 1.74
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm -- Sample Wt 20 mg Picatinny Arsenal Apparatus, in. (c) 14 Sample Wt, mg 18	Boiling Point: °C	
	Refractive Index, n ₂₀ ^D n ₂₅ ^D n ₃₀ ^D	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe ---	Vacuum Stability Test: cc/40 Hrs, at 90°C ---- 100°C 0.47 120°C 135°C 150°C	
Rifle Bullet Impact Test: Trials (b) % Explosions 80 Partial -- Burned -- Unaffected 20	200 Gram Bomb Sand Test: Sand, gm 49.5	
Explosion Temperature: °C (a) Seconds, 0.1 (no cap used) --- 1 --- 5 610(min) (c) 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate ---- Lead Azide 0.20 Tetryl 0.10	
75°C International Heat Test: % Loss in 48 Hrs	Ballistic Mortar, % TNT: (d) 135	
	Trauzl Test, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs 0.78 % Loss, 2nd 48 Hrs 0.00 Explosion in 100 Hrs None	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
Flammability Index:	Detonation Rate: (a, b) Confinement None Condition Cast Charge Diameter, in. 1.0 Density, gm/cc 1.71 Rate, meters/second 7191	
Hygroscopicity: % 30°C, 95% RH, 7 days 2.01 71°C, 95% RH, 7 days 1.77		
Volatility:		

Booster Sensitivity Test: Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc	Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH , kcal/mol) Temperature Range, °C Phase
Heat of: Combustion, cal/gm 3972 Explosion, cal/gm 923 Gas Volume, cc/gm 733 Formation, cal/gm Fusion, cal/gm 78°C (b) 10.25	Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bombs: Plate Thickness, inches 1 1¼ 1½ 1¾
Specific Heat: cal/gm/°C (b) 30°C 0.269 50°C 0.268	
Burning Rate: cm/sec	
Thermal Conductivity: (b) -3 cal/sec/cm/°C 35°C 1.10×10^{-3}	
Coefficient of Expansion: Linear, Δl /inch 0°C 40 x 10 ⁻⁴ 35°C 83 x 10 ⁻⁴ 70°C 131 x 10 ⁻⁴	
Hardness, Mohs' Scale:	
Young's Modulus: (b) E', dynes/cm² 9.0 x 10 ⁹ E, lb/inch² 1.30 x 10 ⁵ Density, gm/cc 1.71	
Compressive Strength: lb/inch² See below	
Vapor Pressure: °C mm Mercury Compressive Strength: lb/inch² 1083 Density, gm/cc 1.71 Ultimate deformation, % 1.32	Bomb Drop Test: T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete: Max Safe Drop, ft 500-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order 1000-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order

Fragmentation Test: (b) 90 mm HE, M71*Projectile, Lot EGS-1-17: Density, gm/cc Charge Wt, lb Total No. of Fragments: For Composition B 998 For Subject HE 714 For 80/20 Tritonal 616 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Color: Gray
Blast (Relative to TNT): (a) Air: 3.25" diameter sphere Peak Pressure Δ psi Catenary 25.4 Impulse NFOC Pendulum 19.8 Energy ---- Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Principal Uses: HE charge
	Method of Loading: Cast
	Loading Density: gm/cc 1.71
	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation None

Effect of Altitude, Charge Diameter and Degree of Confinement on Detonation Velocity*

(Reference e)

<u>Explosive</u>	<u>Simulated Altitude, Feet</u>	<u>One-Inch Column</u>		<u>Two-Inch Column</u>	
		<u>Confined m/s</u>	<u>Unconfined m/s</u>	<u>Confined m/s</u>	<u>Unconfined m/s</u>
TNT, density, gm/cc 1.59	Ground	6820	6720	6670	5270
	30,000	6660	6930(2)	6610	6760(4)
	60,000	6800	-	6520	6400(4)
	90,000	6810	6720	6550	6610(1)
Average		6798	6790	6588	6260
H-6, density, gm/cc 1.69	Ground	7190	7360	7340	6870
	30,000	7300(2)	7430	7360	7980
	60,000	7280	7490	7550	7010
	90,000	7300(3)	7270	7500	7000
Average		7268	7385	7438	7215

*Confined charge in 1/4" steel tube, AISI 1015 seamless, 1" diameter 18" long, and 2" diameter 7" long. All means were determined from sets of five values unless otherwise indicated by (). A 26 gm tetryl booster was used to initiate each charge.

Average Fragment Velocities at Various Altitudes* (e)

<u>Explosive</u>	<u>Charge Diameter, Inches</u>	<u>Simulated Altitude, Feet</u>			
		<u>Ground m/s</u>	<u>30,000 m/s</u>	<u>60,000 m/s</u>	<u>90,000 m/s</u>
TNT, density, gm/cc 1.51	1	2940	2991	3119	2868
	2	3623	4191	5077	4980
H-6, density, gm/cc 1.71	1	3461	3405	3467	3563
	2	4603	4726	4998	5288

*Outside diameter 2.54"; inside diameter 2.04"; length 7".

References:

See HBX-1; HBX-3 reference list.

(In recognition of its development as a military explosive by the late Dr. G. C. Hale of Picatinny Arsenal.)

Composition: % C 16.0 H 4.0 N 37.3 O 42.7 C/H Ratio 0.066		$ \begin{array}{c} \text{H}_2\text{C} - \text{N} \begin{array}{l} \nearrow \text{NO}_2 \\ \searrow \text{H} \end{array} \\ \\ \text{H}_2\text{C} - \text{N} \begin{array}{l} \nearrow \text{NO}_2 \\ \searrow \text{H} \end{array} \end{array} $		Molecular Weight: ($\text{C}_2\text{H}_6\text{N}_4\text{O}_4$) 150
		Oxygen Balance: CO ₂ % -32 CO % -10.5		
		Density: gm/cc	Crystal	1.71
		Melting Point: °C	Decomposes	175+
		Freezing Point: °C		
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 48 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 14 Sample Wt, mg 17		Boiling Point: °C		
		Refractive Index, n_{20}^D n_{25}^D n_{30}^D		
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected		Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.5 120°C 1.5 135°C -- 150°C 11+		
Rifle Bullet Impact Test: Trials Explosions 0 Partial 60 Burned 20 Unaffected 20		200 Gram Bomb Sand Test: Sand, gm 52.3		
Explosion Temperature: °C Seconds, 0.1 (no cap used) 265 1 216 5 Decomposes 189 10 178 15 173 20 170		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.21 Lead Azide 0.13 Tetryl --		
75°C International Heat Test: % Loss in 48 Hrs 0.01		Ballistic Mortar, % TNT: (a) 139		
100°C Heat Test: % Loss, 1st 48 Hrs 0.2 % Loss, 2nd 48 Hrs 0.3 Explosion in 100 Hrs None		Trauzl Test, % TNT: (b) 122		
		Plate Dent Test: (c) Method A Condition Pressed Confined Yes Density, gm/cc 1.50 Brisance, % TNT 122		
Flammability Index: 138		Detonation Rate: Confinement Unconfined Condition Pressed Charge Diameter, in. 1.0 Density, gm/cc 1.49 Rate, meters/second 7570		
Hygroscopicity: % 0.01				
Volatility: Nil				

Booster Sensitivity Test: Condition (d) Pressed Tetryl, gm 100 Wax, in. for 50% Detonation 2.09 Wax, gm Density, gm/cc 1.42	Decomposition Equation: (e) (e) (f) Oxygen, atoms/sec $10^{12.8}$ $10^{12.1}$ $10^{11.1}$ (Z/sec) Heat, kilocalorie/mole 30.5 37.3 30.8 (ΔH , kcal/mol) Temperature Range, °C 184-254 -- 144-164 Phase Liquid Solid Solid
Heat of: Combustion, cal/gm 2477 Explosion, cal/gm 1276 Gas Volume, cc/gm 908 Formation, cal/gm 134 Fusion, cal/gm	Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bombs: Plate Thickness, inches 1 1¼ 1½ 1¾
Specific Heat: cal/gm/°C	
Burning Rate: cm/sec	
Thermal Conductivity: cal/sec/cm/°C	
Coefficient of Expansion: Linear, %/°C Volume, %/°C	Bomb Drop Test: T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete: Max Safe Drop, ft 500-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order 1000-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order
Hardness, Mohs' Scale:	
Young's Modulus: E', dynes/cm ² E, lb/inch ² Density, gm/cc	
Compressive Strength: lb/inch ²	
Vapor Pressure: °C mm Mercury	

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc 1.61 Charge Wt, lb -- Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: <u>95/5 Haleite/wax</u> Density, gm/cc 1.56 Charge Wt, lb -- Total No. of Fragments: For TNT 514 For Subject HE 600	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: White Principal Uses: Booster
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Method of Loading: Pressed <div style="display: flex; justify-content: space-between;"> <div> Loading Density: gm/cc 5 10 12 1.28 1.38 1.41 </div> <div> psi x 10³ 15 20 1.44 1.49 </div> </div>
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Exudation None

Compatibility with Metals:

Dry - Copper, brass, aluminum, mild steel, stainless steel, mild steel coated with acid-proof black paint, and mild steel plated with copper nickel, cadmium or zinc are unaffected. Magnesium and magnesium-aluminum alloy are slightly affected.

Wet - Copper, brass, mild steel coated with acid-proof black paint, and mild steel plated with copper, cadmium, nickel or zinc are heavily corroded. Aluminum is slightly affected and stainless steel is unaffected.

Impact Sensitivities of Various Crystal Habits:

Bureau of Mines Impact Test, 2 Kg Wt:

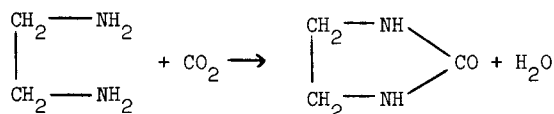
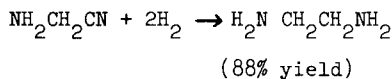
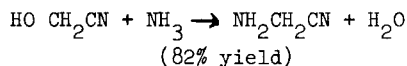
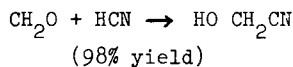
<u>Habit</u>	<u>cm</u>
1st plate	55
2nd plate	55
Bi-pyramid	71
Bracydome	66
Sphenoid	46

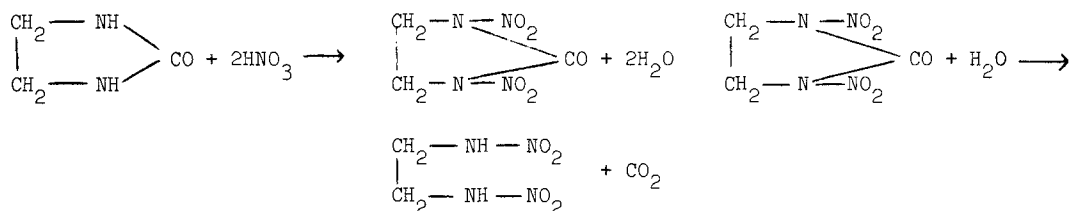
Solubility: gm/100 gm (%) of:

<u>Water</u>		<u>Alcohol</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
20	0.25	20	1.00
40	0.75	40	2.46
60	2.13	60	5.29
80	6.38	78	10.4
100	>20		

Preparation:

(Summary Technical Report of the NDRC, Div 8, Vol 1)



Haleite (Ethylene Dinitramine) (EDNA)

The raw materials used in this process are cheap and available; the first three reactions proceed smoothly, rapidly and in good yield (70% overall), and only the third requires high pressures. The reaction of ethylenediamine with carbon dioxide at about 220°C and 820 atmospheres has been worked out and is more satisfactory for the preparation of ethyleneurea than the use of chlorethyl carbonate or urea and better than the reaction of acetic anhydride and ethylenediamine to yield N,N'-diacetyl-ethylenediamine which can be treated in a way similar to the above to yield Haleite.

Ethyleneurea is very easily nitrated, with strong nitric acid (98%), at ordinary temperature, and in a very short time, and the dinitroethyleneurea produced appears to hydrolyze, yielding Haleite, immediately after solution in water at 95°C. Both the nitration and hydrolysis are practically quantitative.

Origin:

First described in 1877 by Franchimont and Klobbie (Rec trav chim 7, 17 and 244) but it was 1935 before its value as an explosive was recognized. Standardized during World War II as a military explosive.

Destruction by Chemical Decomposition:

Haleite is decomposed by addition to hot, dilute sulfuric acid. Nitrous oxide, acetaldehyde and ethylene glycol are evolved. Haleite is also decomposed by addition to 5 times its weight of 20% sodium hydroxide.

References:³³

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) Report AC-2983/Org Ex 179.
- (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (d) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.
- (e) R. J. Finkelstein and G. Gamow, Theory of the Detonation Process, NAVORD Report No. 90-46, 20 April 1947.
- (f) M. A. Cook and M. Taylor Abbeg, "Isothermal Decomposition of Explosives," University of Utah, Ind Eng Chem (June 1956) pp. 1090-1095.

³³See footnote 1, page 10.

(g) Also see the following Picatinny Arsenal Technical Reports on Haleite:

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
1200	1231	1162	1113	414	1255	786	897	1198	1279
1290	1451	1232	1493	1294	1325	1796	1737	1288	1319
1360	1651	1252	1923	1434	1395		1797	1378	1379
1380		1352			1885		1937	1388	1469
1400		1372						1838	1489
1600									2179

Composition: % RDX 40 TNT 38 Aluminum 17 D-2 Wax 5 Calcium Chloride, added 0.5 C/H Ratio	Molecular Weight: 102	
	Oxygen Balance: CO ₂ % -68 CO % -35	
	Density: gm/cc	Cast 1.72
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm -- Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 16 Sample Wt, mg 21	Boiling Point: °C	
	Refractive Index, n_{20}^D n_{25}^D n_{30}^D	
	Vacuum Stability Test: (a, b) cc/40 Hrs, at 90°C ---- 100°C 0.47 120°C 0.98 135°C ---- 150°C 11+	
Friction Pendulum Test: (b) Steel Shoe Unaffected Fiber Shoe ---	200 Gram Bomb Sand Test: Sand, gm 48.1	
Rifle Bullet Impact Test: Trials (b) % Explosions 73 Partials -- Burned -- Unaffected 28	Explosion Temperature: °C (a) Seconds, 0.1 (no cap used) --- 1 --- 5 480 10 15 20	
	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate ---- Lead Azide 0.20 Tetryl 0.10	
	Ballistic Mortar, % TNT: (a) 133	
	Trauzl Test, % TNT:	
	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
75°C International Heat Test: % Loss in 48 Hrs	Detonation Rate: (a, b) Confinement None Condition Cast Charge Diameter, in. 1.0 Density, gm/cc 1.69 Rate, meters/second 7224	
100°C Heat Test: (b) % Loss, 1st 48 Hrs 0.058 % Loss, 2nd 48 Hrs 0.00 Explosion in 100 Hrs None		
Flammability Index:		
Hygroscopicity: % 30°C, 95% RH, 7 days 2.98 71°C, 95% RH, 7 days 1.13		
Volatility:		

Booster Sensitivity Test: Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc	(c) Cast 100 1.25 1.73	Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH , kcal/mol) Temperature Range, °C Phase
Heat of: Combustion, cal/gm Explosion, cal/gm Gas Volume, cc/gm Formation, cal/gm Fusion, cal/gm	(b) 3882 919 758 78°C 9.25	Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bombs: Plate Thickness, inches 1 1¼ 1½ 1¾
Specific Heat: cal/gm/°C 30°C 50°C	(b) 0.249 0.264	
Burning Rate: cm/sec		Bomb Drop Test: T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete: Max Safe Drop, ft 500-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order 1000-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order
Thermal Conductivity: cal/sec/cm/°C	(b) 35°C 0.97 x 10 ⁻³	
Coefficient of Expansion: Linear, $\Delta L/\Delta T$ 0°C 35°C 70°C	(b) 46 x 10 ⁻⁴ 95 x 10 ⁻⁴ 159 x 10 ⁻⁴	
Hardness, Mohs' Scale:		
Young's Modulus: E', dynes/cm² E, lb/inch² Density, gm/cc	(b) 10.3 x 10 ⁹ 1.49 x 10 ⁻⁵ 1.69	
Compressive Strength: lb/inch²	See below	
Vapor Pressure: °C mm Mercury Compressive Strength: lb/inch² Density, gm/cc Ultimate deformation, %	(b) 1303 1.69 1.38	

Fragmentation Test: (b) 90 mm HE, M71 Projectile, Lot EGS-1-17: Density, gm/cc Charge Wt, lb Total No. of Fragments: For Composition B 998 For Subject HE 910 For 80/20 Tritonal 616 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Color: Gray
Blast (Relative to TNT): (a) Air: 3.25" diameter sphere Peak Pressure Δ psi Catenary 24.7 Impulse NFOC Pendulum 19.6 Energy ---- Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Principal Uses: HE charge
	Method of Loading: Cast
	Loading Density: gm/cc 1.69
	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation None

Composition:			Molecular Weight: 64	
%			Oxygen Balance:	
RDX	31		CO ₂ %	-75
TNT	29		CO %	-49
Aluminum	35		Density: gm/cc Cast 1.84	
D-2 Wax	5		Melting Point: °C	
Calcium Chloride, added	0.5		Freezing Point: °C	
C/H Ratio			Boiling Point: °C	
Impact Sensitivity, 2 Kg Wt:			Refractive Index, n_{20}^D	
Bureau of Mines Apparatus, cm	--		n_{25}^D	
Sample Wt 20 mg			n_{30}^D	
Picatinny Arsenal Apparatus, in.	15		Vacuum Stability Test: (a, b)	
Sample Wt, mg	23		cc/40 Hrs, at	
Friction Pendulum Test:			90°C	----
Steel Shoe	Unaffected		100°C	0.45
Fiber Shoe	---		120°C	
Rifle Bullet Impact Test: Trials (b)			135°C	
	%		150°C	
Explosions	78		200 Gram Bomb Sand Test: (b)	
Partials	--		Sand, gm	44.9
Burned	--		Sensitivity to Initiation:	
Unaffected	22		Minimum Detonating Charge, gm	
Explosion Temperature: °C (a)			Mercury Fulminate	----
Seconds, 0.1 (no cap used)	---		Lead Azide	0.20
1	---		Tetryl	0.10
5	500		Ballistic Mortar, % TNT: (a) 111	
10			Trauzl Test, % TNT:	
15			Plate Dent Test:	
20			Method	
75°C International Heat Test:			Condition	
% Loss in 48 Hrs			Confined	
100°C Heat Test: (b)			Density, gm/cc	
% Loss, 1st 48 Hrs	0.70		Brisance, % TNT	
% Loss, 2nd 48 Hrs	0.00		Detonation Rate: (a, b)	
Explosion in 100 Hrs	None		Confinement	None
Flammability Index:			Condition	Cast
Hygroscopicity: % 30°C, 95% RH, 7 days 2.01			Charge Diameter, in.	1.0
(b) 71°C, 95% RH, 7 days 0.31			Density, gm/cc	1.81
Volatility:			Rate, meters/second	6917

Booster Sensitivity Test: Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc	Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH , kcal/mol) Temperature Range, °C Phase
Heat of: Combustion, cal/gm Explosion, cal/gm Gas Volume, cc/gm Formation, cal/gm Fusion, cal/gm	Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bombs: Plate Thickness, inches 1 1¼ 1½ 1¾
Specific Heat: cal/gm/°C 30°C 50°C	(b) 4495 877 491 9.30 0.254 0.254
Burning Rate: cm/sec	
Thermal Conductivity: cal/sec/cm/°C 35°C	(b) 1.70×10^{-3}
Coefficient of Expansion: Linear, ΔL /inch 0°C 35°C 70°C	(b) 40 x 10 ⁻⁴ 83 x 10 ⁻⁴ 130 x 10 ⁻⁴
Hardness, Mohs' Scale:	
Young's Modulus: E', dynes/cm² E, lb/inch² Density, gm/cc	(b) 11.5×10^9 1.67×10^5 1.81
Compressive Strength: lb/inch²	See below
Vapor Pressure: °C mm Mercury Compressive Strength: lb/inch² Density, gm/cc Ultimate deformation, %	Bomb Drop Test: T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete: Max Safe Drop, ft 500-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order 1000-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order

Fragmentation Test: 90 mm HE, M71 Projectile, Lot EGS-1-17: Density, gm/cc Charge Wt, lb Total No. of Fragments: For Composition B 998 For Subject HE 476 For 80/20 Tritonal 616 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Color: Gray
Blast (Relative to TNT): (a) Air: 3.25" diameter sphere Peak Pressure Δ psi Catenary 25.5 Impulse NFOC Pendulum 20.6 Energy ---- Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Principal Uses: HE charge
	Method of Loading: Cast
	Loading Density: gm/cc 1.81
	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation None

The Stability of HBX Compositions Made With and
Without Desiccants and Containing Added Moisture *

<u>Explosive Composition</u>	<u>Moisture, %</u>	<u>Acidity, %</u>	<u>100°C Vac Stab Test</u>		<u>Hygroscopicity, % 95% RH</u>	
			<u>cc gas</u>	<u>Hours</u>		
					<u>30°C</u>	<u>71°C</u>
<u>Standard HBX-1</u>	0.73	0.011	0.47	40	+2.98	+1.13
+0.2% moisture			0.68	40		
+0.4% moisture			0.62	40		
+0.6% moisture			0.50	40		
<u>HBX-1 without CaCl₂</u>	0.00	0.029	0.36	40	-0.06	-0.25
+0.2% moisture			0.25	40		
+0.4% moisture			0.23	40		
+0.6% moisture			0.27	40		
<u>HBX-1 with silica gel</u>	0.06	0.031	0.73	40	+0.08	+0.04
<u>Standard HBX-3</u>	0.54	0.012	0.45	40	+2.01	+0.31
+0.2% moisture			0.47	40		
+0.4% moisture			0.43	40		
+0.6% moisture			0.41	40		
<u>HBX-3 without CaCl₂</u>	0.02	0.049	0.46	40	-0.06	-0.29
+0.2% moisture			0.26	40		
+0.4% moisture			0.26	40		
+0.6% moisture			0.20	40		
<u>HBX-3 with silica gel</u>	0.04	0.100	0.45	40	+0.09	+0.05
<u>Standard H-6</u>	0.71	0.017	0.47	40	+2.01	+1.77
+0.2% moisture			0.88	40		
+0.4% moisture			0.63	40		
+0.6% moisture			0.65	40		
<u>H-6 without CaCl₂</u>	0.03	0.082	0.40	40	-0.06	-0.25
+0.2% moisture			0.10	40		
+0.4% moisture			0.25	40		
+0.6% moisture			0.23	40		
<u>H-6 with silica gel</u>	0.05	0.028	0.43	40	+0.09	+0.06

* All samples were ground to 20/100 mesh size, 7 days before tests. Silica gel used was Fisher Scientific Company, Lot 541492, through 100 mesh U. S. Standard Sieve.

HBX-1; HBX-3Preparation:

HBX explosive mixtures are prepared by melting TNT in a steam-jacketed melt kettle equipped with a mechanical stirrer. Water-wet RDX is added slowly with stirring and heating until all the water is evaporated. Aluminum is added, and the composition is stirred until uniform. D-2 wax and calcium chloride are then added. The desensitizer wax, also known as Composition D-2, consists of 84% paraffin and other waxes, 14% nitrocellulose and 2% lecithin. The mixture is cooled from approximately 95° to 100°C to a temperature considered suitable for casting (the lowest practicable pour temperature). HBX can also be made by adding the calculated amount of TNT to Composition B to obtain the desired proportion of RDX/TNT. The appropriate weights of the other ingredients are added to complete the mixture.

Origin:

Developed during World War II, as relatively insensitive mixtures, by adding 5% desensitizer to Torpex II, for high blast explosive applications.

References:³⁴

(a) O. E. Sheffield, Blast Properties of Explosives Containing Aluminum or Other Metal Additives, PATR No. 2353, November 1956.

(b) S. D. Stein, G. J. Horvat and O. E. Sheffield, Some Properties and Characteristics of HBX-1, HBX-3 and H-6, PATR No. 2431, June 1957.

(c) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Teteryl in Boosters, NOL Memo. 10,303, 15 June 1949.

(d) S. R. Walton, Report on the Program to Develop an Improved HBX-Type Explosive, NAVORD Report No. 1502, 26 July 1950.

(e) A. W. O'Brien, Jr., C. W. Plummer, R. P. Woodburn and V. Philipchuk, Detonation Velocity Determinations and Fragment Velocity Determinations of Varied Explosive Systems and Conditions, National Northern Corporation Final Summary Report NNC-F-13, February 1958 (Contract DAI-19-020-501-ORD-(P)-58).

(f) Also see the following Picatinny Arsenal Technical Reports on HBX Explosives: 1756, 2138, 2169.

³⁴See footnote 1, page 10.

Composition: % Potassium Perchlorate 32 (17 microns) Aluminum, atomized 48 (20 microns) RDX (through 325 mesh) 16 Asphaltum (through 100 mesh) 4 C/H Ratio	Molecular Weight: 47.6	
	Oxygen Balance: CO ₂ % -42 CO % -34	
	Density: gm/cc Apparent 1.39 Pressed at 20,000 psi 2.1	
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm -- Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 16 Sample Wt, mg 24	Boiling Point: °C	
	Refractive Index, n ₂₀ ^D n ₂₅ ^D n ₃₀ ^D	
	Vacuum Stability Test: cc/40 Hrs, at 90°C ---- 100°C 1.25 120°C 135°C 150°C	
Friction Pendulum Test: Steel Shoe Detonates Fiber Shoe Unaffected	200 Gram Bomb Sand Test: Sand, gm 12.5	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected	Explosion Temperature: °C Seconds, 0.1 (no cap used) --- 1 --- 5 520 10 15 20	
	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate ---- Lead Azide 0.20 Tetryl 0.25	
	Ballistic Mortar, % TNT:	
	Trauzl Test, % TNT:	
	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
75°C International Heat Test: % Loss in 48 Hrs	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
100°C Heat Test: % Loss, 1st 48 Hrs 0.15 % Loss, 2nd 48 Hrs 0.00 Explosion in 100 Hrs None		
Flammability Index:		
Hygroscopicity: % None		
Volatility: None		

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones Hole Volume Hole Depth																				
	Color: Gray																				
	Principal Uses: HE filler for small caliber projectiles																				
	Method of Loading: Pressed																				
	Loading Density: gm/cc Pressed at 20,000 psi 2.1																				
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Dry Hazard Class (Quantity-Distance) Compatibility Group Exudation None																				
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Static Tests: <u>20 mm T215E1 Projectile:</u> PA Peak Pressure, psi 55 NFOC 20" Blast Cube 44 APG 24" Blast Cube 44 Static Tests: <u>20 mm M97 Projectile:</u> <table><tr><td></td><td><u>HEX-24</u></td><td><u>Tritonal</u></td><td><u>Torpex</u></td></tr><tr><td>Foxboro psi</td><td>19</td><td>12.4</td><td>13.0</td></tr><tr><td>Catenary psi</td><td>46</td><td>----</td><td>----</td></tr><tr><td>Duration, microsec</td><td>533</td><td>----</td><td>----</td></tr><tr><td>APG 24" Blast Cube</td><td>36</td><td>24</td><td>32</td></tr></table>		<u>HEX-24</u>	<u>Tritonal</u>	<u>Torpex</u>	Foxboro psi	19	12.4	13.0	Catenary psi	46	----	----	Duration, microsec	533	----	----	APG 24" Blast Cube	36	24	32
	<u>HEX-24</u>	<u>Tritonal</u>	<u>Torpex</u>																		
Foxboro psi	19	12.4	13.0																		
Catenary psi	46	----	----																		
Duration, microsec	533	----	----																		
APG 24" Blast Cube	36	24	32																		
<u>Flame Temperature, °K</u> 2552 <u>Activation Energy, kcal</u> 20.4 <u>Temp, °C</u> 450 to 570 Specific reaction rate, k 1.64 x 10 ⁻⁵	Heat of: Combustion, cal/gm 4197 Explosion, cal/gm 1858 Gas volume, cc/gm 159																				

Composition: % Potassium Perchlorate 32 (17 microns) Aluminum, flaked (1 micron) 48 RDX (through 325 mesh) 16 Asphaltum (through 100 mesh) 4 C/H Ratio	Molecular Weight: 47.6	
	Oxygen Balance: CO ₂ % -42 CO % -34	
	Density: gm/cc Apparent Pressed at 20,000 psi 0.69 1.62	
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	Boiling Point: °C	
	Refractive Index, n_{20}^D n_{25}^D n_{30}^D	
Friction Pendulum Test: Steel Shoe Partially detonates Fiber Shoe Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C ---- 100°C 1.52 120°C 135°C 150°C	
	200 Gram Bomb Sand Test: Sand, gm 23.7	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected	Explosion Temperature: °C Seconds, 0.1 (no cap used) --- 1 --- 5 545 10 15 20	
	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate ---- Lead Azide 0.20 Tetryl 0.25	
75°C International Heat Test: % Loss in 48 Hrs	Ballistic Mortar, % TNT:	
	Trauzl Test, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
Flammability Index:		
Hygroscopicity: %		
Volatility:		

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones Hole Volume Hole Depth Color: Gray Principal Uses: HE filler for small caliber projectiles Method of Loading: Pressed Loading Density: gm/cc Pressed at 20,000 psi 1.62 Storage: Method Dry Hazard Class (Quantity-Distance) Compatibility Group Exudation None																										
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Static Tests: <u>20 mm T215E1 Projectile:</u> PA Peak Pressure, psi 77 NFOC 20" Blast Cube 45 APG 24" Blast Cube 42 Static Tests: <u>20 mm M97 Projectile:</u> <table><tr><td></td><td>HEX-48</td><td>TNT</td><td>Tetryl</td></tr><tr><td>Fosboro psi</td><td>17.3</td><td>2.8</td><td>3.5</td></tr><tr><td>Catenary psi</td><td>43</td><td>28</td><td>28</td></tr><tr><td>Duration, microsec</td><td>517</td><td>560</td><td>530</td></tr><tr><td>APG 24" Blast Cube</td><td>29</td><td>---</td><td>10</td></tr></table> Heat of: <table><tr><td>Combustion, cal/gm</td><td>4119</td></tr><tr><td>Explosion, cal/gm</td><td>1735</td></tr><tr><td>Gas Volume, cc/gm</td><td>200</td></tr></table>		HEX-48	TNT	Tetryl	Fosboro psi	17.3	2.8	3.5	Catenary psi	43	28	28	Duration, microsec	517	560	530	APG 24" Blast Cube	29	---	10	Combustion, cal/gm	4119	Explosion, cal/gm	1735	Gas Volume, cc/gm	200
	HEX-48	TNT	Tetryl																								
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Gas Volume, cc/gm	200																										
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy <u>Flame Temperature, °K</u> 2382 <u>Activation Energy, kcal</u> 25.4 Temp, °C 450 to 470 Specific reaction rate, k 7.84 x 10 ⁻⁶																											

Cook-Off Tests: (c)20 mm T215E1 HEX-48 Loaded Projectiles With Dye-Coated RDX Top-Off

Projectile No.	Cut-Off Temp. °C	Cook-Off
1	170	Yes (198)
2	150	No
3	155	Yes (190)
4	150 to 175	No

National Northern Projectile Load:

MOX-2B (no top-off)	195
MOX-2B (Tetryl top-off)	150
MOX-2B (97/3, RDX/wax top-off)	175
MOX-2 (no top-off)	175

Fragment Penetration Tests: (c)

Projectile	Filler	Altitude, Feet	Avg. No. of Penetrations per Round in Zone 65°-130°		
			0.020"	0.040"	0.051"
T215E1	HEX-48	Ground	352	264	282
		60,000	676	432	388
T282E1	MOX-2B	Ground	634	290	235
		60,000	807	367	250
EX8 Mod 0	MOX-2B	Ground	476	268	224
		60,000	672	264	256

The fragment penetration test records numbers of complete penetrations of aluminum panels of various thicknesses at 2.5 feet from the static detonation. The total penetrations recorded on the 24ST-3 aluminum panels occurred with the projectile nose always pointed toward 0° and the base toward 180°.

The test data indicate that on the thicker panels, 0.040" and 0.051," the HEX-48 loaded T215E1 projectile produced more complete fragment penetrations at ground and altitude than MOX-2B loaded T282E1 and EX8 Mod 0 projectiles.

Preparation:

The HEX compositions were prepared by blending the appropriate weight of the dry ingredients in a Patterson-Kelly twin-shell blender for at least 30 minutes.

An alternate procedure for 100 to 200 gram batches used a "Cradle-Roll" mixing device. This device consisted of a half-barrel type container constructed of wood and lined with an electrical conductive material. A plastic roll was allowed to move over the ingredients by remote control action of the container. The roll action prevented caking of the mix but had no adverse effect on the particle size of the ingredients. The period of time required to obtain a uniform and intimate mixture was approximately fifteen minutes.

Origin:

The development of "slow-burning" explosive mixtures which would produce increased blast effects in enclosed or nearly enclosed spaces directed attention to their use for possible military application. In 1950 Picatinny Arsenal developed a high capacity filler for 20mm projectiles consisting of 85/10/5 RDX/aluminum/desensitizer which was more powerful than standard tetryl filler. However, in comparison with MOX type explosives, there was little doubt as to the superior performance of the MOX mixture. HEX (high energy explosive) mixtures were developed at Picatinny Arsenal in 1953 (Ref a) as superior high blast compositions suitable for use in small caliber projectiles.

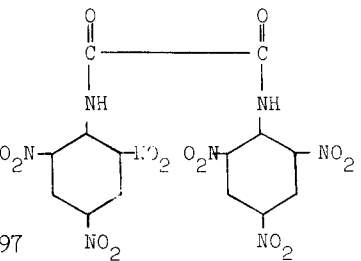
References:³⁵

(a) O. E. Sheffield and E. J. Murray, Development of Explosives—Metallized Explosives—High Blast Fillers for Small Caliber Shell, Picatinny Arsenal Memorandum Report No. MR-49, 21 December 1953.

(b) O. E. Sheffield, Properties of MOX-Type Explosive Mixtures, PATR No. 2205, October 1955.

(c) National Northern Corporation, Letter from Dr. C. M. Saffer, Jr., to Commanding Officer, Picatinny Arsenal, 12 June 1957.

³⁵See footnote 1, page 10.

Composition: % C 33.0 H 1.2 N 21.9 O 43.9 C/H Ratio 0.797				Molecular Weight: (C ₁₄ H ₆ N ₈ O ₁₄)	
				Oxygen Balance: CO ₂ % -53.4 CO % -9.4	
				Density: gm/cc	
				Melting Point: °C Decomposes 302	
				Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm -- Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 15 Sample Wt, mg 12				Boiling Point: °C	
				Refractive Index, n _D ²⁰ n _D ²⁵ n _D ³⁰	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected				Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.40 120°C 135°C 150°C	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected				200 Gram Bomb Sand Test: Sand, gm 52.1	
Explosion Temperature: °C Seconds, 0.1 (no cap used) -- 1 -- 5 384 10 15 20				Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate -- Lead Azide 0.30 Tetryl 0.25	
75°C International Heat Test: % Loss in 48 Hrs				Ballistic Mortar, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs 0.07 % Loss, 2nd 48 Hrs 0.05 Explosion in 100 Hrs None				Trauzl Test, % TNT:	
Flammability Index:				Plate Dent Test: Method Condition Confined Density, gm/cc Brissance, % TNT	
Hygroscopicity: % 25°C, 90% RH 0.19				Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
Volatility:					

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="text-align: right;">Glass Cones Steel Cones</div> Hole Volume Hole Depth
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Color: Almost white
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Principal Uses: Igniter powder; pyrotechnic compositions
	Method of Loading: Pressed and extruded
	Loading Density: gm/cc
	Storage: <div style="text-align: right;">Method Dry</div> <div style="text-align: right;">Hazard Class (Quantity-Distance) Class 9</div> <div style="text-align: right;">Compatibility Group</div> <div style="text-align: right;">Exudation None</div>

Solubility in the following substances:Solvent

Nitrobenzene	<3 gm in 100 cc, at 23°C ~ 5 gm in 100 cc, at 210°C
Water	0.10 gm in 100 cc, at 100°C
Alcohol (Ethyl)	Insoluble
Acetone	Insoluble
Benzene	Insoluble
Butyl acetate	Insoluble
Carbon tetrachloride	Insoluble
Dimethylformamide	Very soluble
Ether (Ethyl)	Insoluble
Acetic Acid	Insoluble
Nitric Acid	Soluble
Crystalline form	Long rectangular glistening plates from nitrobenzene

Preparation:

To prepare hexanitro-oxanilide, first prepare tetranitro-oxanilide as described herein under the entry "2,4,2',4'-Tetranitro-oxanilide (TNO)."

A 1.5 liter round bottom flask is equipped with a stirrer of the type which causes a downward swirl. The flask is jacketed for hot and cold water. 187 grams of nitric acid of specific gravity 1.49 (commercial grade) is placed into the flask and 100 grams of sulphuric acid is added to the nitric acid under agitation. The mixed acid is cooled to 10°C. 29.2 grams of tetranitro-oxanilide is slowly added to the mixed acid under rapid agitation maintaining the temperature at 8°-10°C. After the addition of the TNO is completed (approximately 25 minutes) the temperature is raised to 85°C over a period of 2 hours and held at 85°-90°C for one hour. The hexanitro-oxanilide (HNO) "slurry" is filtered on a Büchner funnel and purified as explained under "Tetranitro-oxanilide."

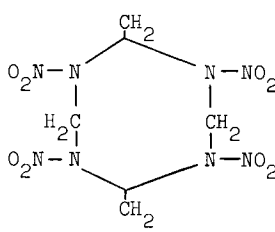
Origin:

A. G. Perkin in 1892 obtained hexanitro-oxanilide directly by heating to boiling a solution of tetranitro-oxanilide in a mixture of sulfuric and nitric acids. He also prepared the same compound from oxanilide by the action of a boiling mixture of fuming nitric and sulfuric acids (J Chem Soc 61, 462 (1892)).

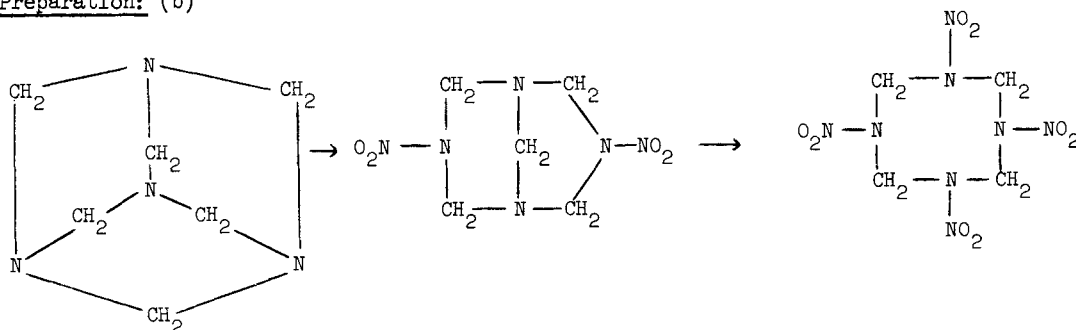
References: ³⁶

- (a) L. Gowen and R. Dwiggens, Case Gun Ignition Studies, NAVORD Report No. 2321, 13 June 1952.
- (b) D. Dubrow and J. Kristal, Substitution of Tetranitro Oxanilide and Hexanitro Oxanilide for Tetranitro Carbazole, PA Pyrotechnic Research Laboratory Report 54-TF1-88, 20 December 1954.
- (c) S. Livingston, Preparation of Tetranitro Carbazole, PA Chemical Research Laboratory Report 136,330, 11 April 1951.
- (d) S. Livingston, Development of Improved Ignition Type Powders, PATR No. 2267, July 1956.

³⁶See footnote 1, page 10.

Composition: %			Molecular Weight: (C ₄ H ₈ N ₈ O ₈) 296		
C	16.2		Oxygen Balance:		
H	2.7		CO ₂ % -21.6		
N	37.9		CO % 0.0		
O	43.2		Density: gm/cc Crystal 1.90		
C/H Ratio 0.095			Melting Point: °C Capillary method 273 Koffler Micro Hot Stage 280		
			Freezing Point: °C		
Impact Sensitivity, 2 Kg Wt:			Boiling Point: °C		
Bureau of Mines Apparatus, cm 32			Refractive Index, n _D ²⁰ n _D ²⁵ n _D ³⁰		
Sample Wt 20 mg					
Picatinny Arsenal Apparatus, in. 9					
Sample Wt, mg 23			Vacuum Stability Test:		
Friction Pendulum Test:			cc/40 Hrs, at		
Steel Shoe Explodes			90°C		
Fiber Shoe Unaffected			100°C 0.37		
Rifle Bullet Impact Test: Trials			120°C 0.45		
%			135°C --		
Explosions			150°C 0.62		
Partials			200 Gram Bomb Sand Test:		
Burned			Sand, gm 60.4		
Unaffected			Sensitivity to Initiation:		
Explosion Temperature: °C			Minimum Detonating Charge, gm		
Seconds, 0.1 (no cap used) 380			Mercury Fulminate		
1 --			Lead Azide 0.30		
5 327			Tetryl		
10 306			Ballistic Mortar, % TNT: 150		
15 --			Trauzl Test, % TNT: 145		
20 --			Plate Dent Test:		
75°C International Heat Test:			Method		
% Loss in 48 Hrs			Condition		
100°C Heat Test:			Confined		
% Loss, 1st 48 Hrs 0.05			Density, gm/cc		
% Loss, 2nd 48 Hrs 0.03			Brisance, % TNT		
Explosion in 100 Hrs None			Detonation Rate:		
Flammability Index:			Confinement		
Hygroscopicity: %			Condition		
30°C, 95% RH (c) 0.00			Charge Diameter, in.		
Volatility:			Density, gm/cc 1.84		
			Rate, meters/second 9124		

Booster Sensitivity Test: Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc	Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH, kcal/mol) Temperature Range, °C Phase	(e) 10 ^{19.7} 52.7 271-314 Liquid
Heat of: Combustion, cal/gm Explosion, cal/gm (e) Gas Volume, cc/gm Formation, cal/gm (e) Fusion, cal/gm		2362 1356 -60.5
Specific Heat: cal/gm/°C °C -75 0 25 50 75	Recrystallized (g) °C 85 90 100 125 150	0.288 0.290 0.295 0.307 0.315
Burning Rate: cm/sec		
Thermal Conductivity: cal/sec/cm/°C		
Coefficient of Expansion: Linear, %/°C Volume, %/°C		
Hardness, Mohs' Scale: (e)	2.3	
Young's Modulus: E', dynes/cm² E, lb/inch² Density, gm/cc		
Compressive Strength: lb/inch²		
Vapor Pressure: °C	mm Mercury	
	Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bombs: Plate Thickness, inches 1 1¼ 1½ 1¾	
	Bomb Drop Test: T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete: Max Safe Drop, ft 500-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order 1000-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order	

Preparation: (b)

Two men are required to regulate the addition of reagents and control the temperature during the initial stage addition; one man can complete the procedure. A 1-liter 5-necked flask is used, the center neck for an efficient stirrer, one side neck for a thermometer, and the other necks for burrettes and a gas outlet (to water trap). The flask is placed in a pan with steam and cold water inlets, for temperature control.

Five cc of acetic anhydride and 250 cc glacial acetic acid are poured into the flask and the temperature brought to $45 \pm 1^\circ\text{C}$, and held there for the duration of the entire reaction. The reagents (a solution of 33.6 gm hexamine in 55 gm of glacial acetic acid, 100 cc of acetic anhydride and 40 cc of a solution of 42.3/57.7-ammonium nitrate/98% nitric acid) are then added simultaneously, continuously and equivalently over a 25-minute period. The reaction mixture is aged 15 minutes.

The second stage reagents (60 cc of 42.3/57.7, ammonium nitrate/98% nitric acid and 150 cc acetic anhydride) are then added simultaneously, continuously and equivalently over a 25-minute period. The mixture is aged 65 minutes, poured into 1.5 liter of water and simmered on a steam bath for 12 hours. Cool, filter and dry the RDX-HMX precipitate (yield 73% HMX).

The RDX is destroyed, leaving HMX, as follows: 1025 gm of the crude product are placed in a solution of 15 gm sodium tetraborate decahydrate in 5 liters of water, heated to boiling with agitation, and 5 N NaOH added at the rate of 3 cc/min. When about 730 cc have been added the pH increases sharply from a little over 8.7 to over 9.7 which corresponds to complete destruction of the RDX. Filter the HMX from the hot mixture; yield 612 gm, mp 279.5°C - 280.5°C . Recrystallization from nitromethane yields material melting at 281°C - 282°C .

Origin:

Was discovered as an impurity (by-product) in the nitration of hexamethylene-tetramine to form RDX. It is now manufactured directly by the process described above and has valuable use in explosive systems.

Removal of RDX from HMX-RDX Mixtures and Recovery of a RDX-HMX Mixture (This procedure appears suitable for use with mixtures containing 80% or more HMX):

Procedure:

500 grams of HMX containing 12.25% RDX are placed in a 1500 cc beaker, 500 cc of acetone is added and the slurry is agitated for several minutes at room temperature. Before complete settling, the RDX-HMX-acetone solution is decanted.

To the residual HMX-RDX, another 500 cc of acetone is added. The slurry is heated on the steambath and while boiling, agitated for several minutes. The boiling RDX-HMX-acetone solution is decanted. The residual HMX is now washed with cold acetone into a funnel. This HMX is now taken up in 95% alcohol, filtered and dried. Yield 353.9 gm or 70.78%.

All the acetone extracts are combined and evaporated to dryness. Yield 137.5 gm or 26.5%.

Yield Balance:

Pure HMX obtained -	353.9 gm	70.78%
Total RDX-HMX mixture recovered -		
137.5 gm		26.50%
Samples taken during process -		
2.4 gm		0.48%
Loss during process		<u>2.24%</u>
Total		100.00%

Various samples were analyzed for RDX content:

1. Crude HMX	12.25% RDX
2. After first acetone washing	6.0% RDX
3. After second acetone washing	2.0% RDX
4. After third acetone washing	0.0% RDX
RDX-HMX sample recovered	54.5% RDX

Preparation of Fine Particle-size HMX by the Aspirator Method:

1. Dissolve 1100 gm HMX in 4400 cc of dimethyl sulfoxide.
2. Filter the HMX solution.
3. Connect a clean aspirator to the water line.
4. Place a 55 gallon clean drum under the aspirator.
5. Fasten a polyethylene tubing, long enough to reach easily to the bottom of the HMX-dimethyl sulfoxide container, to the side intake of the aspirator.
6. Fasten to the bottom of the aspirator another polyethylene tube long enough to reach to the bottom of the 55 gallon drum.
7. Open the water faucet and then place the polyethylene tube in the HMX container.
8. White milky fine HMX separates out in the drum. Total duration of run is approximately 7 minutes.
9. After all the HMX solution is sucked out of the container, the water is turned off.
10. The material is filtered and water washed.
11. If dry HMX is required, the material can be alcohol and ether washed.

A more efficient method to recover the RDX-HMX mixture:

1. Filter the combined hot acetone extracts.
2. Pour while agitating the filtered extracts into at least 4 times its volume of water.
3. Filter and dry, etc.

Color:

White

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group L (dry) Group M (wet)
Exudation	None

References:³⁷

(a) O. E. Sheffield, E. J. Murray, A. L. Rosen and B. W. Kanouse, Properties of HMX, PA Chemical Research Laboratory Report No. 52-TM1-23, 7 April 1952.

(b) W. E. Bachmann, The Preparation of HMX, OSRD Report No. 1981, 3 November 1943.

(c) S. Livingston, Characteristics of Explosives HMX and DPEHN, PATR No. 1561, 6 September 1945.

(d) R. J. Finkelstein and G. Gamow, Theory of the Detonation Process, NAVORD Report No. 90-46, 20 April 1947.

(e) O. H. Johnson, HMX as a Military Explosive, NAVORD Report No. 4371, 1 October 1956.

(f) Also see the following Picatinny Arsenal Technical Reports on HMX:

<u>1</u>	<u>3</u>	<u>6</u>	<u>7</u>	<u>9</u>
1741	2183	2016	1737	1709 2059

(g) C. Lenchitz, W. Beach and R. Valicky, Enthalpy Changes, Heat of Fusion and Specific Heat of Basic Explosives, PATR No. 2504, January 1959.

³⁷See footnote 1, page 10.

Composition: % HMX 49 TNT 29 Aluminum 22 C/H Ratio	Molecular Weight: 91	
	Oxygen Balance: CO ₂ % -51 CO % -27	
	Density: gm/cc	Cast 1.90
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm -- Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 17 Sample Wt, mg 25	Boiling Point: °C	
	Refractive Index, n_{20}^D n_{25}^D n_{30}^D	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C ---- 100°C ---- 120°C 0.37 135°C 150°C	
	200 Gram Bomb Sand Test: Sand, gm 61.3	
Rifle Bullet Impact Test: 10 Trials, % 3/16" Steel 1/8" Al Explosions 90 50 Partial -- -- Burned 10 -- Unaffected 0 50	Explosion Temperature: °C Seconds, 0.1 (no cap used) --- 1 --- 5 Flames erratically 370 10 15 20	
	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate ---- Lead Azide 0.30 Tetryl ----	
75°C International Heat Test: % Loss in 48 Hrs	Ballistic Mortar, % TNT: 120	
	Trauzl Test, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
	Detonation Rate: Confinement None Condition Cast Charge Diameter, in. 1.0 Density, gm/cc 1.90 Rate, meters/second 7866	
Flammability Index:		
Hygroscopicity: %		
Volatility:		

Booster Sensitivity Test: Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc	Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH , kcal/mol) Temperature Range, °C Phase
Heat of: Combustion, cal/gm 3687 Explosion, cal/gm 1190 Gas Volume, cc/gm 680 Formation, cal/gm ---- Fusion, cal/gm	Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bombs: Plate Thickness, inches 1 1¼ 1½ 1¾
Specific Heat: cal/gm/°C 32° to 74°C 0.245	
Burning Rate: cm/sec	
Thermal Conductivity: cal/sec/cm/°C	
Coefficient of Expansion: Linear, %/°C Volume, %/°C	
Hardness, Mohs' Scale:	
Young's Modulus: E', dynes/cm ² E, lb/inch ² Density, gm/cc	
Compressive Strength: lb/inch ² 2260 See below	
Vapor Pressure: °C mm Mercury Compressive Strength: lb/inch ² * Average (10 tests) 2260 High 2530 Low 1910	Bomb Drop Test: T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete: Max Safe Drop, ft 500-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order 1000-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order
	Ultimate Deformation: % Average (10 tests) 2.81 High 3.22 Low 2.52

* Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Gray Principal Uses: HE projectile and bomb filler Method of Loading: Cast Loading Density: gm/cc 1.90
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation None
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Work to Produce Rupture: ft-lb/inch³ * <div style="display: flex; justify-content: space-between;"> Average (10 tests) 2.77 </div> <div style="display: flex; justify-content: space-between;"> High 3.39 </div> <div style="display: flex; justify-content: space-between;"> Low 2.40 </div> <u>Efflux Viscosity, Saybolt Seconds:</u> 24.8 <p>*Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.</p>

Modulus of Elasticity: *

	lb/inch ²
Average	89,200
High	97,400
Low	76,300

* Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.

Setback Sensitivity Test: (a)

Critical Pressure	119,000 psi *
Density, gm/cc	1.92

* Pressure below which no initiation is obtained and above which an increasing percentage of initiations can be expected as the setback pressure increases.

Preparation:

Procedure similar to that used for Torpex.

References:³⁸

(a) 1st Indorsement from Chief, Explosives Development Section, to Chief, Explosives Research Section, Picatinny Arsenal, dated 12 May 1958. Subject: "Properties of Octols and HTA-3."

(b) R. Brown and R. Velicky, Heat Capacity of HTA-3, Picatinny Arsenal General Laboratory Report No. 58-HL-509, 5 May 1958.

³⁸See footnote 1, page 10.

AMCP 706-177

Lead Azide

Composition: % N 28.8 Pb 71.2 $\text{N} \equiv \text{N} = \text{N} - \text{Pb} - \text{N} = \text{N} \equiv \text{N}$ C/H Ratio	Molecular Weight: (PbN_6) 291		
	Oxygen Balance: CO_2 % -5.5 CO % -5.5		
	Density: gm/cc Crystal 4.80 Dextrinated 4.38		
	Melting Point: °C Decomposes		
	Freezing Point: °C		
Impact Sensitivity, 2 Kg Wt: <u>Pure</u> <u>Dextrinated</u> Bureau of Mines Apparatus, cm 10 17 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 3 5 Sample Wt, mg 30 28	Boiling Point: °C		
	Refractive Index, n_{20}^D n_{25}^D n_{30}^D		
	Friction Pendulum Test: Steel Shoe Explodes Fiber Shoe Explodes		
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected	Vacuum Stability Test: <u>Dextrinated</u> cc/40 Hrs, at 90°C 100°C 1.0 120°C 0.07 135°C 150°C		
	200 Gram Bomb Sand Test: Sand, gm Black powder fuse 19.0		
	Explosion Temperature: °C Seconds, 0.1 (no cap used) 396 1 356 5 Explodes 340 10 335 15 335 20 335		
75°C International Heat Test: % Loss in 48 Hrs 100°C Heat Test: % Loss, 1st 48 Hrs 0.34 % Loss, 2nd 48 Hrs 0.05 Explosion in 100 Hrs None	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl		
	Ballistic Mortar, % TNT:		
	Trauzl Test, % TNT: (a) 39		
Flammability Index: Hygroscopicity: % <u>Dextrinated</u> <u>Not Dextrinated</u> 30°C, 90% RH 0.8 0.03 Volatility:	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT		
	Detonation Rate: <u>Pure Lead Azide</u> Confinement Condition Pressed Charge Diameter, in. Density, gm/cc 2.0 3.0 4.0 Rate, meters/second 4070 4630 5180		

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: White-buff Principal Uses: Detonators, priming compositions, and commercial blasting caps Method of Loading: Pressed Loading Density: gm/cc psi x 10 ³ <div style="display: flex; justify-content: space-around;"> <div>3 2.62</div> <div>5 2.71</div> <div>10 2.96</div> <div>15 3.07</div> </div>
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Wet Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group M (wet) Exudation None
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy <u>Heat of:</u> Combustion, cal/gm 630 Explosion, cal/gm 367 Gas Volume, cc/gm 308 Formation, cal/gm -346	<u>Compatibility with Metals:</u> Dry lead azide does not react with or corrode steel, iron, nickel, aluminum, lead, zinc, copper, tin or cadmium. It does not affect coatings of acid-proof black paint, oil, NRC compound or shellac. Lead azide in the presence of moisture corrodes zinc and copper; and with copper, it forms the extremely sensitive and dangerous copper azide. <u>Specific Heat:</u> cal/gm/°C <div style="display: flex; justify-content: space-between;"> <div>°C</div> <div></div> </div> <div style="display: flex; justify-content: space-between;"> <div>-50</div> <div>0.110</div> </div> <div style="display: flex; justify-content: space-between;"> <div>0</div> <div>0.110</div> </div> <div style="display: flex; justify-content: space-between;"> <div>25</div> <div>0.110</div> </div> <div style="display: flex; justify-content: space-between;"> <div>50</div> <div>0.110</div> </div> <u>Thermal Conductivity:</u> cal/sec/cm/°C (Pure) 1.55 x 10 ⁻⁴

Compatibility with Metals:

Dry: Steel, iron, nickel, aluminum, lead, zinc, copper, tin, stainless steel, brass and bronze were unaffected by six years' contact with dry lead azide at ambient temperature and 50°C. Monel, chrome-nickel and Inconel were unaffected under the same conditions in two and one-half years.

Wet: Copper and zinc are rapidly attacked by moist lead azide, while aluminum is not attacked in 24 hours. Monel, chrome-nickel and Inconel are not attacked by lead azide ($\frac{1}{2}\%$ moisture) after 29 months' exposure at ambient temperature and 50°C, and J-1 magnesium-aluminum alloy is very slightly corroded.

<u>Sample Tested</u>	<u>Lead Azide</u> <u>Dry</u>	<u>Lead Azide</u> <u>plus</u> <u>25% Water</u>	<u>Lead Azide</u> <u>plus</u> <u>20% Water</u>	<u>Lead Azide</u> <u>plus 20%</u> <u>Ethyl Alco-</u> <u>hol (95%)</u>

Friction Pendulum Test:

(All IA dextrinated)

<u>Shoe</u>	<u>Fiber</u>	<u>Fiber</u>	<u>Steel</u>	<u>Fiber</u>	<u>Steel</u>	<u>Fiber</u>
No. of Trials	1	10	12	10	4	1
Explosions	1	0	0	0	1	1
Cracklings		0	2	0	2	0
Unaffected	0	10	10	10	1	0

Impact Sensitivity, 2 Kg Wt:

(All IA dextrinated)

PA Apparatus, inches	4	9	9	4
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Activation Energy: (c)

Kcal/mole	23.74
Induction Period, seconds	0.5-10

Initiating Efficiency, Grams Required to Give Complete Initiations of:

	<u>Dextrinated Azide (gm)</u>
TNT	0.25
Tetryl	0.10
RDX	0.05
PETN	0.02

Sensitivity to Static Discharge, Joules (Pure Lead Azide) (b) 0.0070

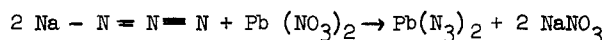
Compatibility of Dextrinated Lead Azide with Black Powder:
100°C Vacuum Stability Test, cc/40 hr:

<u>Sample Wt (gm)</u>	<u>Material</u>	<u>cc</u>
1.0	Lead Azide	0.50
1.0	Black Powder	0.38
2.0	50/50, Lead Azide/Black Powder	1.26

Solubility of Pure Lead Azide; gm/100 gm of Water:

<u>°C</u>	<u>%</u>
20	0.05

Preparation of Lead Azide (Dextrinated): (du Pont procedure)



Lead nitrate solution: This is prepared by dissolving 164 lbs lead nitrate and 8.25 lbs dextrine in deionized water, the solution allowed to settle, and sodium hydroxide added to bring the solution to a pH of 5.4. The final concentration of the solution is then adjusted to 7.4% lead nitrate, 0.375% dextrine by addition of deionized water.

The lead azide is precipitated at a solution temperature of 160°F, using 60 parts lead nitrate and 50 parts sodium azide solution. The latter is added to the former in 23 minutes, under agitation (no baffles are used in the precipitation vessel), the mixture cooled to room temperature in 12 minutes, and allowed to settle 10 minutes. The mother liquor is decanted and the remaining slurry washed before packing.

Origin:

First prepared in 1891 by T. Curtius (Ber 24, 3345-6) by adding lead acetate to a solution of sodium or ammonium azide. F. Hyronimus (French Patent 384,792) should be credited with the first attempt in 1907 to use lead azide with some success in the explosive industry. Its commercial manufacture started in Europe before World War II and in the United States since 1931 as military or commercial grade "dextrinated" lead azide.

Destruction by Chemical Decomposition:

Lead azide can be decomposed by

(1) mixing with at least five times its weight of a 10% solution of sodium hydroxide and allowing the mixture to stand for 16 hours. Decant the supernatant solution of sodium azide and drain into the soil.

(2) dissolving in a 10% solution of ammonium acetate and adding a 10% solution of sodium or potassium bichromate until no more lead chromate is precipitated.

(3) wetting with 500 times its weight of water, slowly adding 12 times its weight of 25% sodium nitrite, stirring, and then adding 14 times its weight of 36% nitric or glacial acetic acid. A red color produced by the addition of ferric chloride solution indicates Lead Azide is still present.

(4) dissolving in 50 times its weight of 15% ceric ammonium nitrate. The azide is decomposed with the evolution of nitrogen.

References:³⁹

(a) Ph. Naoum, Z ges Schiess Sprengstoffw, 181, 229, 267 (27 June 1932).

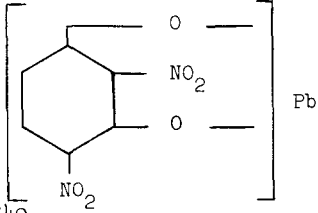
(b) F. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.

(c) C. Lenchitz, Ice Calorimeter Determination of Enthalpy and Specific Heat of Eleven Organometallic Compounds, PATR #2224, November 1955.

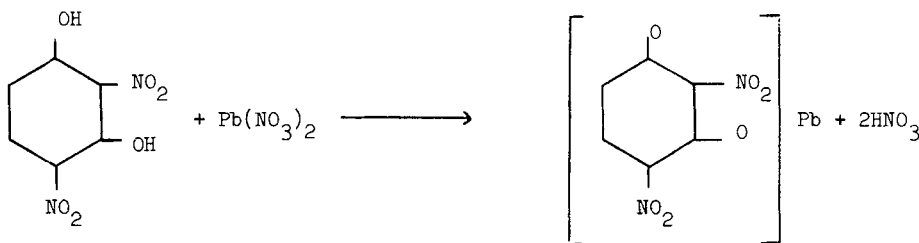
(d) Also see the following Picatinny Arsenal Technical Reports on Lead Azide:

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
550	561	832	393	534	255	326	567	628	609
580	861	852	1393	784	525	856	637	708	719
600	1451	882	1493	824	1325	866	657	748	749
760	1651	932	2093	944	1485	1316	707	788	769
1450		1132	2133	2164		1486	1737	838	849
		1152		2204		1556	2227	1388	999
		1352						1528	2179
		1372						1838	
								2198	

³⁹See footnote 1, page 10.

Composition: % C 17.8 H 0.5 N 6.9 O 23.7 Pb 51.1 C/H Ratio 0.549 	Molecular Weight: (PbC ₆ H ₂ N ₂ O ₆) 405 Oxygen Balance: CO ₂ % -32 CO % -8 Density: gm/cc Crystal 3.2 Melting Point: °C Freezing Point: °C
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 1 kg wt 30 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg 20	Boiling Point: °C Refractive Index, n ₂₀ ^D n ₂₅ ^D n ₃₀ ^D
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C (73 minutes) Explodes 135°C 150°C
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm Black powder fuse 20
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Explodes 265 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl
75°C International Heat Test: % Loss in 48 Hrs	Ballistic Mortar, % TNT:
100°C Heat Test: % Loss, 1st 48 Hrs 0.20 % Loss, 2nd 48 Hrs 0.02 Explosion in 100 Hrs None	Trauzl Test, % TNT:
Flammability Index:	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT
Hygroscopicity: % 30°C, 90% RH 0.73	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second
Volatility:	

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Red or yellow Principal Uses: Electric detonators Method of Loading: Pressed Loading Density: gm/cc
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: <div style="display: flex; justify-content: space-around;"> Method Wet </div> <div style="display: flex; justify-content: space-around;"> Hazard Class (Quantity-Distance) Class 9 </div> <div style="display: flex; justify-content: space-around;"> Compatibility Group </div> <div style="display: flex; justify-content: space-around;"> Exudation None </div>
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	<u>Initiating Efficiency:</u> 0.4 gm LDNR does not initiate tetryl pressed at 3000 psi. <u>Heat of:</u> <div style="display: flex; justify-content: space-around;"> Explosion, cal/gm 270 </div>

Preparation:

To a solution of 5 grams of purified dinitroresorcin and 2.65 grams of anhydrous sodium carbonate in 500 cc of boiling water is added slowly a solution of 10 grams of lead nitrate dissolved in 60 cc of boiling water. The reaction mixture is constantly stirred during the addition of the lead salt and for about an hour afterward while the solution is allowed to cool to room temperature. The precipitate is filtered and washed thoroughly first with water and then with alcohol and ether. It is dried in a steam oven.

Origin:

2,4-dinitroresorcin was described in the 1881 edition of Beilstein (Beil VII, 885). The same compound was described in more detail by Weselsky, Benedikt and Hübl in 1882 (M II, 323). The lead salt of 2,4-dinitroresorcinol appears to have been prepared between World War I and World War II by treating resorcinol with nitrous acid and oxidizing the resulting dinitrosoresorcinol to dinitroresorcinol. Lead nitrate solution was then added to a solution of the 2,4-dinitroresorcinol to which sodium carbonate had been added to form the soluble sodium salt (J. D. Hopper, PATR No. 480, March 1934). The LDNR exists in two forms differing in physical characteristics but possessing similar explosive properties. These forms are red and orange in color (K. S. Warren, PATR 1448, September 1944).

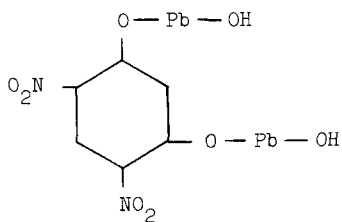
References:⁴⁰

- (a) See the following Picatinny Arsenal Technical Reports on Lead 2,4-Dinitroresorcinate:

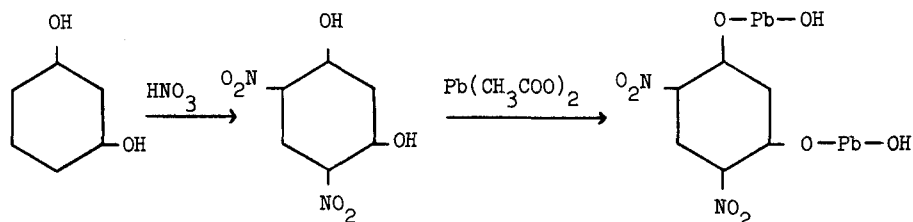
<u>0</u>	<u>3</u>	<u>4</u>	<u>8</u>	<u>9</u>
480	453	1004	1328	859
580			1448	1079

⁴⁰See footnote 1, page 10.

Composition: % C 11.2 H 0.6 N 4.3 O 19.8 Pb 64.1 C/H Ratio 0.177	Molecular Weight: ($\text{Pb}_2\text{C}_6\text{H}_4\text{N}_2\text{O}_8$) 646 Oxygen Balance: CO ₂ % -20 CO % -5 Density: gm/cc Melting Point: °C 213 Freezing Point: °C Boiling Point: °C Refractive Index, n_{20}^D n_{25}^D n_{30}^D
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 1 kg wt 60 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg 20	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C
Friction Pendulum Test: Steel Shoe Fiber Shoe	200 Gram Bomb Sand Test: Sand, gm Black powder fuse 15
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Explodes 295 10 15 20	Ballistic Mortar, % TNT: Trauzl Test, % TNT:
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT
100°C Heat Test: % Loss, 1st 48 Hrs 0.4 % Loss, 2nd 48 Hrs 0.0 Explosion in 100 Hrs None	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second
Flammability Index:	
Hygroscopicity: %	
Volatility:	



Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Red or yellow Principal Uses: Electric detonators Method of Loading: Pressed Loading Density: gm/cc
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: <div style="display: flex; justify-content: space-around;"> Method Wet </div> <div style="display: flex; justify-content: space-around;"> Hazard Class (Quantity-Distance) Class 9 </div> <div style="display: flex; justify-content: space-around;"> Compatibility Group </div> <div style="display: flex; justify-content: space-around;"> Exudation None </div>
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	<u>Initiating Efficiency:</u> 0.4 gm LDNR Basic does not initiate tetryl pressed at 3000 psi.

Preparation:

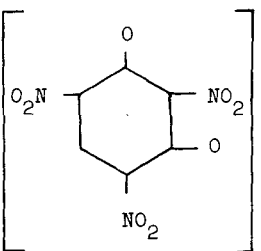
(a) One hundred grams of pure resorcin is fused in a porcelain casserole and immediately poured on a glass plate. After cooling, the cake is ground in a mortar to pass a U. S. Standard No. 6 mesh screen. Four hundred grams of 98 percent nitric acid in a one pint capacity Dewar jar is stirred mechanically while carbon dioxide snow is added in small pieces. When the temperature falls to -20°C , 40 grams of the granulated resorcin is added in small quantities. Simultaneous addition of solid carbon dioxide as required prevents a rise of temperature of more than 5 degrees throughout the entire experiment. Five minutes after the last portion of resorcin is introduced, the mixture is further cooled to minus 50°C , and finally drowned with vigorous stirring in five times its volume of cracked ice, in water. This mixture is allowed to stand for one hour and the product then filtered, washed, and partially dried, weight 43.6 grams. The crude 4,6-DNR is purified by first dissolving the product in an aqueous 5 percent sodium hydroxide solution (17.4 grams of sodium hydroxide in 340 cc of water). The resulting solution is then neutralized by gradually adding it to a boiling solution of 21.4 grams of 98 percent sulphuric acid in 150 cc of water. The resulting precipitate of 4,6-DNR is filtered hot on a suction filter and air-dried. Yield, 27.5 grams (37.8 percent of the theoretical).

(b) Five hundredths (0.05) mole (18.96 grams) of lead acetate is dissolved in 67 cc of warm water, into which is gradually stirred 0.10 mole (4.0 grams) of sodium hydroxide dissolved in 67 cc of water. Stirring is continued for five minutes. After settling, the white lead hydroxide is washed by decantation three times with 100 cc portions of distilled water, and used immediately for the next operation.

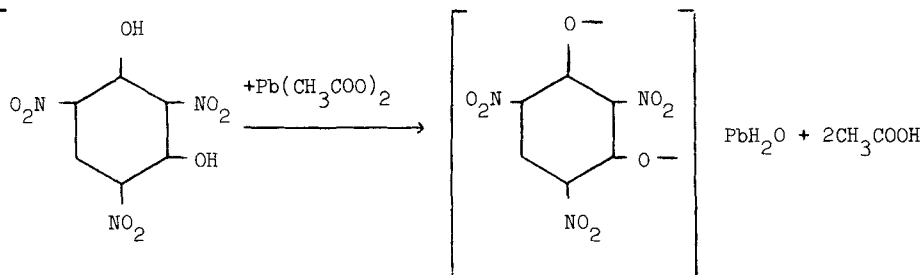
(c) A 0.0278 mole (5.56 grams) quantity of the 4,6-DNR prepared under (a) above, is dispersed in 270 cc of water by vigorously beating with a motor stirrer. After heating this dispersion to 90°C , the 0.05 mole of lead hydroxide prepared above in slurry form is introduced in small portions. Agitation is continued for three hours at 90°C . The basic lead 4,6-DNR is washed once by decantation, and again on the filter with alcohol. After drying overnight in a desiccator charged with calcium chloride, the product weighs 15.6 grams.

Origin:

Both the 2,4- and 4,6-dinitroresorcin were described in some detail by Weselsky, Benedikt and Hübl in 1882 (M II, 323). Typke prepared the 4,6-dinitroresorcin in 1883 by hydrolyzing the nitration product of resorcin diacetate (Ber 16, 551). A more direct and economical method of preparation suitable for production scale manufacture was developed during World War II by the British (Ministry of Supply Pouch Item W-154-21a, "Manufacture of 4,6-Dinitroresorcin and Lead 4,6-Dinitroresorcinat"). This procedure consisted of preparing 4,6-dinitroresorcinol by direct nitration of granulated resorcin and allowing the product in slurry to react with an excess of lead hydroxide at 90°C . This basic salt can be prepared in two forms: (1) a micro-crystalline, yellow, low-density form and (2) a denser, brick-red form. Both products have the same chemical composition and the same sensitivity to impact (PATR 1448, September 1944).

Composition: % C 15.4 H 0.6 N 9.0 O 30.8 Pb 44.2 C/H Ratio 0.320				Molecular Weight: ($\text{PbC}_6\text{H}_3\text{N}_3\text{O}_9$) 468	
				Oxygen Balance: CO_2 % -19 CO % 2	
				Density: gm/cc Crystal 3.02	
				Melting Point: °C Explodes 260-310	
				Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 17 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 3; (8 oz wt) 8 Sample Wt, mg 22				Boiling Point: °C	
				Refractive Index, n_{20}^D n_{25}^D n_{30}^D	
Friction Pendulum Test: Steel Shoe Detonates Fiber Shoe Detonates				Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.4 120°C 0.3 135°C 150°C	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected				200 Gram Bomb Sand Test: Sand, gm 24 Black powder fuse 11.1	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Explodes 282 10 276 15 272 20 267				Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Trace* Lead Azide Trace* * Tetryl <.001 gm, alternative	
				Ballistic Mortar, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs				Trauzl Test, % TNT: (a) 40	
100°C Heat Test: % Loss, 1st 48 Hrs 0.38 % Loss, 2nd 48 Hrs 0.73 Explosion in 100 Hrs None				Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
Flammability Index:				Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc 2.9 Rate, meters/second 5200	
Hygroscopicity: % 25°C, 100% RH 0.05 30°C, 90% RH 0.02					
Volatility:					

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones Hole Volume Hole Depth
	Color: Orange-reddish brown
	Principal Uses: Igniting charge, and ingredient of priming compositions
	Method of Loading: Pressed
	Loading Density: gm/cc
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Wet Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group M (wet) Exudation None
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy <u>Heat of:</u> Combustion, cal/gm 1251 Explosion, cal/gm 457 Gas Volume, cc/gm 368 Formation, cal/gm -92	<u>Activation Energy:</u> kcal/mol 75.39 Induction Period, sec 0.5-10 <u>Specific Heat: cal/cm/°C</u> (c) °C -50 0.141 0 0.158 25 0.164 50 0.167

Preparation:

Dissolve 14.4 gm lead nitrate and 1 cc of 36% acetic acid in 320 cc distilled water. Dissolve 4 gm 2,4,6-trinitroresorcinol and 1.73 gm sodium carbonate in 80 cc distilled water. Add the lead acetate solution to the trinitroresorcinol solution, under agitation, keeping the temperature at 70°-75°C and continue stirring for 3 hours at this temperature. Cool to 20°C in 5 hours. Evaporate the solution to 1/3 its volume, cool, filter and wash the product well with water (to neutrality).

Sensitivity to Static Discharge, joules: (b)

0.0009

Loss in Weight at 105°C: %

3 hours	0.02
6 hours	0.23
9 hours	0.23

Effect of Storage for 2 Months at 80°C, on:

Explosion Temperature Test Value	Nil
Sand Test Value	Nil
Sensitivity to Initiation	Nil

Solubility, gm/100 gm (%) in:

Glycol Diacetate

°C	%
20-25	0.1

Origin:

First described in 1914 by von Hurtz and found to be a relatively poor initiator by Wallbaum in comparison to other primary explosives. (Z ges Schiess Sprengstoffw 34, 126, 161, 197 (1939)). Moisak showed that lead styphnate could be used as an insulating (cover) material for lead azide providing protection from mechanical and chemical influences and, at the same time, increasing the detonating ability of the total charge (Transactions of Butlerov Inst Chem Tech Kasan (Russia) 2, 81-5 (1935)).

Destruction by Chemical Decomposition:

Lead styphnate is decomposed by dissolving it in at least 40 times its weight of 20% sodium hydroxide or 100 times its weight of 20% ammonium acetate and adding a solution of sodium dichromate, equal to half the weight of styphnate and 10 parts of water.

References:⁴¹

(a) Report AC-956/Org Ex 74.

(b) F. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.

(c) C. Lenchitz, Ice Calorimeter Determination of Enthalpy and Specific Heat of Eleven Organometallic Compounds, PATR No. 2224, November 1955.

(d) Also see the following Picatinny Arsenal Technical Reports on Lead Styphnate:

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
1450	11	1352	453	2164	1316	407	318	2179
2220		2032	2093			1737		
						2077		

⁴¹See footnote 1, page 10,

Mannitol Hexanitrate (Nitromannite)

AMCP 706-177

Composition: % C 15.9 H 1.8 N 18.6 O 63.8 C/H Ratio 0.133	$ \begin{array}{c} \text{CH}_2\text{ONO}_2 \\ \\ \text{O}_2\text{NOCH} \\ \\ \text{O}_2\text{NOCH} \\ \\ \text{HCONO}_2 \\ \\ \text{HCONO}_2 \\ \\ \text{CH}_2\text{ONO}_2 \end{array} $	Molecular Weight: ($\text{C}_6\text{H}_8\text{N}_6\text{O}_{18}$) 452
		Oxygen Balance: CO ₂ % 7.1 CO % 28.3
		Density: gm/cc 1.73
		Melting Point: °C 112-113
		Freezing Point: °C
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 11 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 4 Sample Wt, mg 11	Boiling Point: °C Decomposes 150	
	Refractive Index, n_{20}^D n_{25}^D n_{30}^D	
	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C	
Friction Pendulum Test: Steel Shoe Detonates Fiber Shoe Unaffected	200 Gram Bomb Sand Test: Sand, gm 68.5	
	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate -- Lead Azide 0.06 Tetryl --	
Rifle Bullet Impact Test: Trials % Explosions Partial Burned Unaffected	Ballistic Mortar, % TNT:	
	Trauzl Test, % TNT: (c) 172	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 160-170 (a) 1 232 (b) 5 175 (c) 10 15 20	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
	Detonation Rate: (d) Confinement Yes Condition Pressed Charge Diameter, in. 0.5 Density, gm/cc 1.73 Rate, meters/second 8260	
75°C International Heat Test: % Loss in 48 Hrs 0.4	Flammability Index:	
100°C Heat Test: % Loss, 1st 48 Hrs -- % Loss, 2nd 48 Hrs -- Explosion in 100 Hrs (Frothed) 48 hours	Hygroscopicity: % 30°C, 90% RH 0.17	
Volatility:		

<p>Fragmentation Test:</p> <p>90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments: For TNT For Subject HE</p> <p>3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments: For TNT For Subject HE</p> <p>Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc</p>	<p>Shaped Charge Effectiveness, TNT = 100:</p> <table> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table> <p>Color:</p> <p>Principal Uses: Secondary charge in detonators (ref i), and in blasting caps designed to be initiated by a fuse (ref j)</p> <p>Method of Loading: Pressed</p> <p>Loading Density: gm/cc</p>		Glass Cones	Steel Cones	Hole Volume			Hole Depth												
	Glass Cones	Steel Cones																		
Hole Volume																				
Hole Depth																				
<p>Blast (Relative to TNT):</p> <p>Air: Peak Pressure Impulse Energy</p> <p>Air, Confined: Impulse</p> <p>Under Water: Peak Pressure Impulse Energy</p> <p>Underground: Peak Pressure Impulse Energy</p>	<p>Storage:</p> <table> <tr> <td>Method</td> <td>Dry</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td>Class 9</td> </tr> <tr> <td>Compatibility Group</td> <td></td> </tr> <tr> <td>Exudation</td> <td>None</td> </tr> </table> <p><u>65.5°C KI Test:</u></p> <table> <tr> <td>Minutes</td> <td>6</td> </tr> </table> <p><u>Heat of:</u> (e, f, g)</p> <table> <tr> <td>Combustion, cal/gm</td> <td>1515</td> <td>1525</td> </tr> <tr> <td>Explosion, cal/gm</td> <td>1390</td> <td>1454 1468 1520</td> </tr> <tr> <td>Formation, cal/gm</td> <td>337</td> <td>345 366</td> </tr> </table>	Method	Dry	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group		Exudation	None	Minutes	6	Combustion, cal/gm	1515	1525	Explosion, cal/gm	1390	1454 1468 1520	Formation, cal/gm	337	345 366
Method	Dry																			
Hazard Class (Quantity-Distance)	Class 9																			
Compatibility Group																				
Exudation	None																			
Minutes	6																			
Combustion, cal/gm	1515	1525																		
Explosion, cal/gm	1390	1454 1468 1520																		
Formation, cal/gm	337	345 366																		

Solubility:

- a. Insoluble in water.
- b. Slightly soluble in cold alcohol (2.9 gm at 13°C).
- c. Slightly soluble in ether (4 gm at 9°C).
- d. Very soluble in hot alcohol.

Preparation: (Laboratory Method) (k)

a. Cool to below 0°C, 50 gm of 98%-100% nitric acid placed in a 300 milliliter Erlenmeyer Pyrex flask provided with a thermometer and immersed in an ice-salt mixture.

b. Introduce in small portions, 10 gm of d-mannitol, while swirling the flask to break up any lumps of mannite which might form. Keep the temperature below 0°C.

c. After solution is complete, add 100 gm of concentrated sulfuric acid from a dropping funnel, swirling the flask in an ice-salt mixture to keep the temperature below 0°C.

d. Filter the resulting porridge-like slurry through a filter paper previously hardened by treatment with mixed acid.

e. Rinse the precipitate directly on the filter with water followed by dilute aqueous sodium carbonate and finally with water. (The resulting crude mannitol hexanitrate gives 18.2% N as determined by the nitrometer.)

f. Dissolve the crude mannitol hexanitrate in boiling alcohol and filter through a water-heated funnel.

g. Bring the filtrate to boiling and gradually add hot water until the appearance of the first turbidity.

h. Cool in an ice-salt bath, separate and dry the crystals. (Yield should be about 23 gm of material, melting at 112°-113°C and having 18.58% N, the nitrogen being determined by the nitrometer. Theoretical yield would be 24.8 gm.)

Origin:

Mannitol hexanitrate was discovered in 1847 by Ascanio Sobrero who recommended it as a substitute for mercury fulminate in percussion caps (Comp rend, 1847, 121). It is the hexanitric ester of d-mannitol which is widely distributed in nature, particularly in the plant *Fraxinus ornus*. N. Sokoloff, a Russian chemist, investigated the explosive properties of HM and recommended in 1878 a method of preparation. Mannitol hexanitrate was thoroughly studied by Berthelot, Sarrau and Vieille, Domonte, Menard, Strecker, Tichanowich (Ph. Naoum, Nitroglycerin and Nitroglycerin Explosives, Baltimore, 1928, pp. 156, 247-250), and particularly by J. H. Wigner (Ber 36, 796 (1903)). More recent data have been reviewed by Guastalla and Racciu ("Modern Explosives," Industria Chimica 8, 1093-1102 (1933)).

References:⁴²

(a) G. C. Hale, Abstract of Available Information on the Preparation and Explosive Properties of Hexanitromannite, PA Special Report No. 238, 30 July 1925.

⁴²See footnote 1, page 10.

(b) C. A. Taylor and W. H. Rinkenbach, "Sensitiveness of Detonating Compounds to Frictional Impact, Impact, and Heat," J. Frank Inst 204, 369-76 (1927).

(c) Ph. Naoum, Z ges Schiess - Sprengstoffw (Munich), pp. 181, 229, 267 (27 June 1932).

(d) H. Kast, Z angew Chem, 36, 74 (1923).

(e) A. Schmidt, Z ges Schiess - Sprengstoffw 29, 262, (1934).

Landolt and Börnstein, E III, p. 2914.

(f) A. Marshall, Explosives, Their Manufacture, Properties, Tests, and History, Vol III, London (1932) p. 39. Ph. Naoum, Nitroglycerin and Nitroglycerin Explosives, Baltimore, (1928), pp. 156, 247-250.

(g) A. Schmidt, Z ges Schiess - Sprengstoffw 29, 262 (1934) G. Fleury, L. Brissand and P. Lhoste, "Structure and Stability of Nitric Esters," Comp rend 224, 1016-18 (1947). W. R. Tomlinson, Jr., Fundamental Properties of High Explosives. Thermodynamic Relations for Use in the Estimation of Explosive Properties, PATR No. 1651, 22 April 1947.

(h) Sarrau and Vielle, Mém poudr 2, 161 (1884-1889).

(i) E. von Hurtz, U. S. Patent 1,878,652 (20 September 1932).

(j) L. A. Burrows, U. S. Patent 2,427,899 (23 September 1947).

(k) B. T. Fedoroff, Handbook of Explosives and Related Items, Picatinny Arsenal (unpublished).

(l) O. E. Sheffield, Literature Survey on Mannitol Hexanitrate, PA Chemical Research Laboratory Report No. 52-TML-16, 23 January 1952.

(m) Also see the following Picatinny Arsenal Technical Reports on Mannitol Hexanitrate:

<u>2</u>	<u>4</u>	<u>5</u>	<u>6</u>
1352	24	85	6
	64		

Composition: %			Molecular Weight: (HgC ₂ N ₂ O ₂) 285		
C	8.4	<div><div>Hg</div><div><div>O — N = C</div><div>O — N = C</div></div></div>	Oxygen Balance:		
N	9.8		CO ₂ % -17		
O	11.2		CO % -5.5		
Hg	70.6		Density: gm/cc Crystal 4.43		
C/H Ratio			Melting Point: °C Decomposes		
			Freezing Point: °C		
Impact Sensitivity, 2 Kg Wt:			Boiling Point: °C		
Bureau of Mines Apparatus, cm 5; (1 kg wt) 35			Refractive Index, n ₂₀ ^D n ₂₅ ^D n ₃₀ ^D		
Sample Wt 20 mg					
Picatinny Arsenal Apparatus, in. 2; (1 lb wt) 4					
Sample Wt, mg 30			Vacuum Stability Test:		
Friction Pendulum Test:			cc/40 Hrs, at		
Steel Shoe Explodes			90°C		
Fiber Shoe Explodes			100°C Explodes		
Rifle Bullet Impact Test: Trials			120°C		
%			135°C		
Explosions			150°C		
Partials			200 Gram Bomb Sand Test:		
Burned			Sand, gm		
Unaffected			Black powder fuse 23.4		
Explosion Temperature: °C			Sensitivity to Initiation:		
Seconds, 0.1 (no cap used) 263			Minimum Detonating Charge, gm		
1 239			Mercury Fulminate		
5 Explodes 210			Lead Azide		
10 199			Tetryl		
15 194			Ballistic Mortar, % TNT:		
20 190			Trauzl Test, % TNT: (a) 51		
75°C International Heat Test:			Plate Dent Test:		
% Loss in 48 Hrs 0.18			Method		
100°C Heat Test: Exploded in 16 hours			Condition		
% Loss, 1st 48 Hrs			Confined		
% Loss, 2nd 48 Hrs			Density, gm/cc		
Explosion in 100 Hrs			Brisance, % TNT		
Flammability Index:			Detonation Rate:		
Hygroscopicity: % 30°C, 90% RH 0.02			Confinement		
Volatility:			Condition Pressed		
			Charge Diameter, in.		
			Density, gm/cc 2.0 3.0 4.0		
			Rate, meters/second 3500 4250 5000		

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones Hole Volume Hole Depth Color: White to gray Principal Uses: Detonators and ingredient of priming compositions Method of Loading: psi x 10 ³ 3 5 10 12 15 20 3.00 3.20 3.60 3.70 3.82 4.00 Loading Density: gm/cc
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Wet Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group M (wet) Exudation None
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Stab Sensitivity: Density Firing Point (inch-ounces) gm/cc 0% 50% 100% 3.91 3.2 4.3 5.5 4.26 1.6 2.6 5.5 4.32 1.6 2.6 4.0 4.50 1.6 2.5 4.0 Activation Energy: kcal/mol 29.81 Induction Period, sec 0.5-10 Heat of: Combustion, cal/gm 938 Explosion, cal/gm 427 Gas Volume, cc/gm 243 Formation, cal/gm -226 Specific Heat: cal/gm/°C 1.1 Thermal Conductivity: cal/sec/cm/°C 1 x 10 ⁻⁴

Initiating Efficiency; Grams Required to Give Complete Initiation of:

	<u>Fulminate, gm</u>
TNT	0.25
Tetryl	0.20
RDX	0.19
PETN	0.17

Compatibility with Metals:

Dry: Reacts rapidly with aluminum and magnesium. Reacts slowly with copper, zinc, brass and bronze. Iron and steel are not affected.

Wet: Reacts immediately with aluminum and magnesium. Reacts rapidly with copper, zinc, brass and bronze. Iron and steel are not affected.

Sensitivity to Static Discharge, Joules: (b) 0.025

The Effect of Storage at 50°C (Dry) on the Purity of Mercury Fulminate

<u>Months Storage</u>	<u>Recrystallized Lots</u>				<u>Uncrystallized Lots</u>	
	<u>979</u>	<u>980</u>	<u>981</u>	<u>982</u>	<u>505.6-7/31</u>	<u>505.3-5/11</u>
0	99.75	99.77	99.79	99.79	98.86	
4						98.7
6	99.38	99.45	99.54	99.47	95.95	98.7
8						97.4
9					94.95	
10						94.9
12	98.74	99.56	97.49	99.06	90.65	
13	98.26			98.79		
14	98.22					
15	97.52	99.30	99.30	98.19	83.76	
16	97.00		99.01	97.75		
17	95.70	98.66		96.69		
18	94.81	98.58	98.46	95.90	79.99	
23					74.52	
26					63.80	

Chemistry:

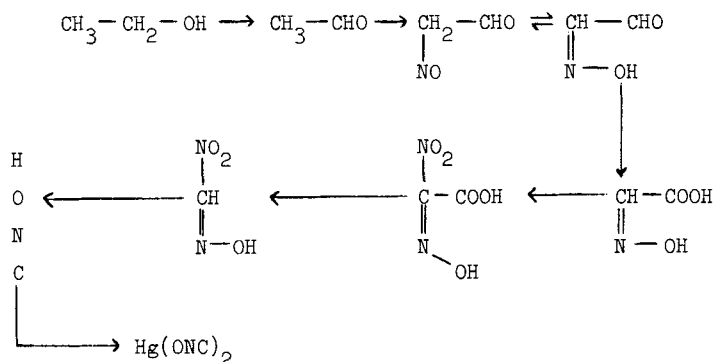
Mercuric fulminate readily decomposes in the presence of aqueous solutions, chlorides, carbonate and many other materials. Due to the presence of small amounts of mercury, formed by exposure to light or elevated temperatures, it readily forms amalgams with copper, brass and bronze, thus components containing these metals must be protectively coated if used with fulminate.

Solubility, Grams of Mercury Fulminate in 100 Grams of Water (%):

<u>°C</u>	<u>%</u>
12	0.07
49	0.18

Preparation:

(Chemistry of Powder and Explosives, Davis)



Five gm mercury is dissolved in 25 cc of nitric acid (sp gr 1.42) without agitation, and this solution poured into 50 cc of 90% ethyl alcohol, resulting in a vigorous reaction, attended by evolution of white fumes and subsequent appearance of fulminate crystals. Red fumes then appear as precipitation of the product accelerates, and then white fumes again are evolved as the reaction moderates. After about 20 minutes the reaction is over; water is added, and the crystals are repeatedly washed, by decantation, with water to remove all acidity. The product is purified, rendered white, by solution in strong ammonium hydroxide, followed by reprecipitation with 30% acetic acid.

Origin:

Mercury fulminate was first prepared by John K. von Lowenstern (1630-1703) and in 1800 its preparation and properties were first described in detail by Edward Howard in a paper presented to the Royal Society of London (Phil Trans, 204 (1800)). It was 1867 before the compound was used as an initiating agent, when Alfred Nobel invented the blasting cap and used mercury fulminate to detonate nitroglycerin (British Patent 1345 (1867)).

Destruction by Chemical Decomposition:

Mercury fulminate is decomposed by adding it, while stirring, to at least 10 times its weight of 20% sodium thiosulfate. Some poisonous cyanogen gas may be evolved.

References:⁴³

- (a) Ph. Naoum - Z ges Schiess-Sprengstoffw (Munich), pp. 181, 229, 267 (27 June 1932).
- (b) F. W. Brown, D. H. Kusler, and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.

⁴³See footnote 1, page 10.

(c) Also see the following Picatinny Arsenal Technical Reports on Mercury Fulminate:

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
250	301	132	23	144	65	266	277	28	199
480	381	452	203	294	105	366	297	78	609
510	561	522	393	534	255	556	407	278	749
550	1651	582	433	624	285	566	537	318	849
610		782	833	694	365	866	567	788	999
680		882	1183	784	415	986	637	1838	1079
760		932	1393	874	425	1316	857		1389
1220		1192	2093	1104	1325	1486	1737		2179
1450		1352			1365	1556			
		1372				2146			
		1722							
		2032							

AMCP 706-177 Metriol Trinitrate (MTN) Liquid (or Trimethylolethane Trinitrate)

Composition: % C 23.5 H 3.5 N 16.6 O 56.4 C/H Ratio 0.150 <div style="text-align: center;"> $\begin{array}{c} \text{O}_2\text{NO}-\text{CH}_2 \\ \text{O}_2\text{NO}-\text{CH}_2 \\ \text{O}_2\text{NO}-\text{CH}_2 \end{array} \begin{array}{c} \diagup \\ \diagdown \\ \diagup \\ \diagdown \\ \diagup \\ \diagdown \end{array} \text{C}-\text{CH}_3$ </div>	Molecular Weight: ($\text{C}_5\text{H}_9\text{N}_3\text{O}_9$) 255	
	Oxygen Balance: CO ₂ % -35 CO % -3	
	Density: gm/cc	Liquid 1.47
	Melting Point: °C -3	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 47; (1 lb wt) 4 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg 20	Boiling Point: °C	
	Refractive Index, n_{20}^D n_{25}^D 1.4752 n_{30}^D	
	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C cc/gm 1.9 120°C 135°C 150°C	
Friction Pendulum Test: Steel Shoe Explodes Fiber Shoe	200 Gram Bomb Sand Test: Sand, gm 43.7	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	
	Ballistic Mortar, % TNT: (a) 136	
	Trauzl Test, % TNT: (b) 140	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Ignites 235 10 15 20	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
75°C International Heat Test: % Loss in 48 Hrs	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
100°C Heat Test: % Loss, 1st 48 Hrs 2.5 % Loss, 2nd 48 Hrs 1.8 Explosion in 100 Hrs None		
Flammability Index:		
Hygroscopicity: % 30°C, 90% RH 0.07		
Volatility: 60°C, mg/cm ² /hr 24		

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Oily, slightly turbid Principal Uses: Ingredient of rocket and double base propellants Method of Loading: Loading Density: gm/cc
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: <div style="display: flex; justify-content: space-between;"> Method Liquid </div> Hazard Class (Quantity-Distance) Compatibility Group Exudation
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	<div style="display: flex; justify-content: space-between;"> <div> Solubility in Water, <u>gm/100 gm, at:</u> <div style="display: flex; justify-content: space-between;"> 25°C < 0.015 </div> <div style="display: flex; justify-content: space-between;"> 60°C < 0.015 </div> </div> <div> Heat of: Combustion, cal/gm 2642 </div> </div> <div style="margin-top: 10px;"> <u>Hydrolysis, % Acid:</u> <div style="display: flex; justify-content: space-between;"> <div>10 days at 22°C</div> <div>0.018</div> </div> <div style="display: flex; justify-content: space-between;"> <div>5 days at 60°C</div> <div>0.115</div> </div> </div>

Preparation:

Metriol (trimethylolmethane) is obtained by the following procedure, based on work by Hosaeus (Annalen 276, 76 (1893):

Into a 5 liter round bottom flask is weighed 2700 gms of water. To this are added 267 gms of 36% formaldehyde and 60 gms of propionaldehyde. The mixture is stirred for a few seconds. To the mixture is added 150 gms of calcium oxide previously slaked with 600 gms of water. The mixture is heated in boiling water for four hours, and then allowed to cool spontaneously overnight. After filtering off the insoluble calcium hydroxide, the solution is heated and treated with a saturated aqueous solution of oxalic acid to precipitate all the calcium. The precipitated calcium oxalate is filtered off, and the pale-yellow filtrate concentrated as much as possible on the steam bath to a thick lemon-yellow syrup. After dissolving in absolute alcohol, the solution is filtered and concentrated in the steam bath to about twice the volume of the concentrated syrup. The solution is then chilled in a cold box to hasten crystallization. After allowing it to warm up to just above 0°C, the mixture is filtered. The resulting product is not sufficiently pure and is recrystallized from absolute alcohol. The melting point of the product (40.3 gm) is then about 196°C (Hosaeus gives 199°C).

Metriol is nitrated by carefully mixing it with 3.5 parts of 65/35 HNO₃/H₂SO₄ maintained at 20°C, stirring for 30 minutes, cooling to 5°C, and pouring the reaction mixture on ice. It is extracted with ether, water-washed, and adjusted to pH 7 by shaking with a sodium bicarbonate solution and again water-washed three times. It is then dried with calcium chloride, filtered, and freed of ether by bubbling with dry air until minimal rate of loss in weight is attained. The yield is 88% of the theoretical. The product has a nitrate-nitrogen content of 16.35% (calculated: 16.47%). Its refractive index at 25°C is 1.4752.

Origin:

MTN, according to Italian sources, was first prepared and patented by Bombrini-Parodi-Delfino Company of Italy under the name "metriolo." A German Patent of 1927 also describes the preparation and gives some properties. This compound was known in France before World War II under the name of "Nitropentaglycerin" and Burlot and Thomas determined its heat of combustion (Ref b).

References:⁴⁴

(a) A. H. Blatt, Compilation of Data on Organic Explosives, OSRD Report No. 2014, 29 February 1944.

(b) E. Burlot and M. Thomas, Mém poudr 29, 262 (1939).

(c) Also see the following Picatinny Arsenal Technical Reports on Metriol Trinitrate: 1616 and 1817.

⁴⁴See footnote 1, page 10.

Composition: % Ammonium Nitrate 40 TNT 40 Aluminum 20 C/H Ratio	Molecular Weight: 71	
	Oxygen Balance: CO ₂ % -38 CO % -20	
	Density: gm/cc 1.62-1.68	
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 35 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 13 Sample Wt, mg 17	Boiling Point: °C	
	Refractive Index, n ₂₀ ^D n ₂₅ ^D n ₃₀ ^D	
	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 2.1 135°C 150°C	
Friction Pendulum Test: Steel Shoe Fiber Shoe	200 Gram Bomb Sand Test: Sand, gm	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	
	Ballistic Mortar, % TNT: (a) 143	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Ignites 435 10 15 20	Trauzl Test, % TNT: (b) 165	
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: (c) Method B Condition Pressed Confined No Density, gm/cc 1.73 Brisance, % TNT 66	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Detonation Rate: (d) Confinement None Condition Cast Charge Diameter, in. 1.6 Density, gm/cc 1.68 Rate, meters/second 5820	
Flammability Index: 100		
Hygroscopicity: %		
Volatility:		

Booster Sensitivity Test: Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc	(e) Pressed 100 1.46 1.74	Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH , kcal/mol) Temperature Range, °C Phase
Heat of: Combustion, cal/gm Explosion, cal/gm Gas Volume, cc/gm Formation, cal/gm Fusion, cal/gm	(f) 3160 1620 	Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bombs: Plate Thickness, inches 1 1¼ 1½ 1¾
Specific Heat: cal/gm/°C At -5°C Density, gm/cc	 0.30 1.74	
Burning Rate: cm/sec		
Thermal Conductivity: cal/sec/cm/°C Density, gm/cc	(b) 16.5 x 10 ⁻⁴ 1.74	
Coefficient of Expansion: Linear, %/°C Volume, %/°C		
Hardness, Mohs' Scale:		
Young's Modulus: E', dynes/cm² E, lb/inch² Density, gm/cc	(b) 5.03 x 10 ¹⁰ 0.73 x 10 ⁶ 1.66	
Compressive Strength: lb/inch² (b) Density, gm/cc	1910-2070 1.68	
Vapor Pressure: °C mm Mercury		Bomb Drop Test: T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete: Max Safe Drop, ft 500-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order 1000-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div> Glass Cones Steel Cones </div> Hole Volume Hole Depth
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Color: Gray
Blast (Relative to TNT): Air: Peak Pressure 115 Impulse 116 Energy 133 Air, Confined: Impulse 90 Under Water: Peak Pressure 108 Impulse 126 Energy 140 Underground: Peak Pressure 134 Impulse 139 Energy 147	Principal Uses: Bombs and depth charges
	Method of Loading: Cast
	Loading Density: gm/cc 1.62-1.68
	Storage: <div> Method Dry </div> <div> Hazard Class (Quantity-Distance) Class 9 </div> <div> Compatibility Group Group I </div> <div> Exudation </div>
	Preparation: Minol is a castable mixture consisting of 40 percent TNT, 40 percent ammonium nitrate, and 20 percent powdered aluminum and therefore can be prepared by adding the dry ingredients to molten TNT at 90°C under agitation. Minol also can be prepared by adding 25 parts of aluminum to 100 parts of 50/50 amatol previously prepared.

Origin:

Minols are British ternary explosives developed during World War II. There are three formulations:

<u>Composition, %:</u>	<u>Minol-1</u>	<u>Minol-2</u>	<u>Minol-3</u>
TNT	48	40	42
Ammonium Nitrate	42	40	38
Aluminum	10	20	20

References:⁴⁵

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.

(c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(d) G. H. Messerly, The Rate of Detonation of Various Explosive Compounds, OSRD Report No. 1219, 22 February 1943.

M. D. Hurwitz, The Rate of Detonation of Various Compounds and Mixtures, OSRD Report No. 5611, 15 January 1946.

(e) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Teteryl in Boosters, NOL Memo 10,303, 15 June 1949.

(f) Committee of Div 2 and 8, NDRC, Report on HBX and Tritonal, OSRD No. 5406, 31 July 1945.

(g) W. R. Tomlinson, Jr., Blast Effects of Bomb Explosives, PA Technical Div Lecture, 9 April 1948.

(h) Also see the following Picatinny Arsenal Technical Reports on Minol-2: 1585 and 1635.

⁴⁵See footnote 1, page 10.

Composition: % Oxidizing agent (Ammonium Perchlorate) 35.0 Aluminum, atomized 26.2 Cupric Oxide ---- Magnesium, atomized 26.2 Other ingredient (Tetryl) 9.7 Calcium Stearate 1.9 Graphite, artificial 1.0 C/H Ratio	Molecular Weight: 40.6	
	Oxygen Balance: CO ₂ % -44 CO % -37	
	Density: gm/cc	Pressed 2.0
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm -- Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 13 Sample Wt, mg 22	Boiling Point: °C	
	Refractive Index, n_{20}^D n_{25}^D n_{30}^D	
	Vacuum Stability Test: cc/40 Hrs, at 90°C ---- 100°C 0.47 120°C 135°C 150°C	
Friction Pendulum Test: Steel Shoe Detonates Fiber Shoe Unaffected	200 Gram Bomb Sand Test: Sand, gm 10.6	
Rifle Bullet Impact Test: Trials % Explosions Partial Burned Unaffected	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate ---- Lead Azide 0.20 Tetryl 0.25	
	Ballistic Mortar, % TNT: Trauzl Test, % TNT:	
Explosion Temperature: °C Seconds, 0.1 (no cap used) --- 1 --- 5 285 10 15 20	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
75°C International Heat Test: % Loss in 48 Hrs Discoloration, fumes, odor None	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
100°C Heat Test: % Loss, 1st 48 Hrs 0.10 % Loss, 2nd 48 Hrs 0.01 Explosion in 100 Hrs None		
Flammability Index:		
Hygroscopicity: %		
Volatility:		

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="text-align: right;">Glass Cones Steel Cones</div> Hole Volume Hole Depth Color: Gray powder mixture Principal Uses: Small caliber antiaircraft projectiles Method of Loading: Pressed
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Loading Density: gm/cc At 30,000 psi ~ 2.0 Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Bureau of Explosives Classification Class A Exudation
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Heat of: Combustion, cal/gm 4087 Explosion, cal/gm 2087 Gas volume, cc/gm 212 Performance Tests: <u>20 mm T215E1 Projectile:</u> NFOC Pressure Cube 35 APG Blast Cube 40 <u>Activation Energy:</u> kcal/mol 12.5 Temp, °C 300 to 380 Time to ignition, seconds 1.78×10^{-4}

Composition: % Oxidizing agent (Ammonium Perchlorate) 35.0 Aluminum, atomized 52.4 Cupric Oxide ---- Magnesium, atomized ---- Other ingredients* 9.7 Calcium Stearate 1.9 Graphite, artificial 1.0 *5.8% RDX and 3.9% TNT coated on Ammonium Perchlorate.	Molecular Weight: 42	
	Oxygen Balance: CO ₂ % -49 CO % -43	
	Density: gm/cc	Pressed 2.0
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm -- Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 12 Sample Wt, mg 24	Boiling Point: °C	
	Refractive Index, n_{20}^D n_{25}^D n_{30}^D	
	Vacuum Stability Test: cc/40 Hrs, at 90°C ---- 100°C 0.21 120°C 135°C 150°C	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	200 Gram Bomb Sand Test: Sand, gm 11.5	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected	Explosion Temperature: °C Seconds, 0.1 (no cap used) --- 1 --- 5 375 10 15 20	
	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate ---- Lead Azide 0.20 Tetryl 0.20	
	Ballistic Mortar, % TNT:	
	Trauzl Test, % TNT:	
	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
75°C International Heat Test: % Loss in 48 Hrs Discoloration, fumes, odor None	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
100°C Heat Test: % Loss, 1st 48 Hrs 0.27 % Loss, 2nd 48 Hrs 0.12 Explosion in 100 Hrs None		
Flammability Index:		
Hygroscopicity: %		
Volatility:		

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Gray Principal Uses: HE filler for small caliber projectiles Method of Loading: Pressed Loading Density: gm/cc 2.0 Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Bureau of Explosives Class A Exudation None																											
Blast (Relative to TNT): <table border="0"> <tr> <td>Air: Bare Charge:</td> <td><u>EW*</u></td> <td><u>EV*</u></td> </tr> <tr> <td>Peak Pressure</td> <td>1.02</td> <td>1.34</td> </tr> <tr> <td>Impulse</td> <td>1.08</td> <td>1.41</td> </tr> <tr> <td>Energy</td> <td></td> <td></td> </tr> <tr> <td>Density, gm/cc</td> <td></td> <td>1.96</td> </tr> </table> Air, Confined: Impulse <u>Cased Charge in Air:**</u> <table border="0"> <tr> <td>Peak Pressure</td> <td>1.09</td> <td>1.44</td> </tr> <tr> <td>Impulse</td> <td>1.16</td> <td>1.53</td> </tr> <tr> <td>Energy</td> <td>----</td> <td>----</td> </tr> <tr> <td>Density, gm/cc</td> <td></td> <td>1.98</td> </tr> </table> Underground: Peak Pressure Impulse Energy *EW, equivalent weight as compared to TNT; EV, equivalent volume as compared to TNT. **Strong paper-base phenolic case.	Air: Bare Charge:	<u>EW*</u>	<u>EV*</u>	Peak Pressure	1.02	1.34	Impulse	1.08	1.41	Energy			Density, gm/cc		1.96	Peak Pressure	1.09	1.44	Impulse	1.16	1.53	Energy	----	----	Density, gm/cc		1.98	Heat of: Combustion, cal/gm 4484 Explosion, cal/gm 1472 Gas volume, cc/gm 221 <u>Performance Tests:</u> <u>20 mm T215E1 Projectile:</u> NFOC Pressure Cube 29 APG Blast Cube 30 <u>Aviation Energy:</u> kcal/mol 7.6 Temp, °C 340 to 470 Time to ignition, seconds 1.39×10^{-2}
Air: Bare Charge:	<u>EW*</u>	<u>EV*</u>																										
Peak Pressure	1.02	1.34																										
Impulse	1.08	1.41																										
Energy																												
Density, gm/cc		1.96																										
Peak Pressure	1.09	1.44																										
Impulse	1.16	1.53																										
Energy	----	----																										
Density, gm/cc		1.98																										

Effect of Altitude, Charge Diameter and Degree of Confinement on Detonation Velocity*
(Reference g)

<u>Simulated Altitude,</u> <u>Feet</u>	<u>One-Inch Column</u>		<u>Two-Inch Column</u>	
	<u>Confined</u>	<u>Unconfined</u>	<u>Confined</u>	<u>Unconfined</u>
	m/s	m/s	m/s	m/s
Ground			4730	
30,000	Charge would not propagate detonation.		4530(3)	Charge would not propagate detonation.
60,000			4430	
90,000			4290	
Average			4495	

*Confined charge in 1/4" steel tube, AISI 1015 seamless, 1" diameter 18" long, and 2" diameter 7" long. All means were determined from sets of five values unless otherwise indicated by (). A 26 gm teteryl booster was used to initiate each charge.

Average Fragment Velocity at Various Altitudes* (g)

<u>Explosive</u>	<u>Charge Diameter,</u> <u>Inches</u>	<u>Simulated Altitude, Feet</u>			
		<u>Ground</u>	<u>30,000</u>	<u>60,000</u>	<u>90,000</u>
		m/s	m/s	m/s	m/s
MOX-2B, density, gm/cc 207	1	2012	**	**	**
	2	3314	3351	3247	**

*Outside diameter 2.54"; inside diameter 2.04"; length 7".

**Charge would not propagate detonation.

Composition: % Oxidizing agent (Potassium Nitrate) 18 Aluminum, atomized 50 Cupric Oxide -- Magnesium, atomized -- Other ingredients* 32 Calcium Stearate** 2.0 Graphite, artificial** 1.0 *29.1% RDX, 0.9% wax, and 2.0% TNT. **Per cent added.	Molecular Weight: 45.6	
	Oxygen Balance: CO ₂ % -52 CO % -43	
	Density: gm/cc	Pressed 2.0
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm -- Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 17 Sample Wt, mg 24	Boiling Point: °C	
	Refractive Index, n ₂₀ ^D n ₂₅ ^D n ₃₀ ^D	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C ---- 100°C 0.57 120°C 135°C 150°C	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm 33.2	
Explosion Temperature: °C Seconds, 0.1 (no cap used) --- 1 --- 5 540 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate ---- Lead Azide 0.20 Tetryl 0.15	
75°C International Heat Test: % Loss in 48 Hrs Discoloration, fumes, odor None	Ballistic Mortar, % TNT:	
	Trauzl Test, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs 0.35 % Loss, 2nd 48 Hrs 0.13 Explosion in 100 Hrs None	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
Flammability Index:	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
Hygroscopicity: %		
Volatility:		

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones Hole Volume Hole Depth
	Color: Gray powder mixture
	Principal Uses: Small caliber antiaircraft

Composition: % Oxidizing agent (Barium Nitrate) 18 Aluminum, atomized 50 Cupric Oxide -- Magnesium, atomized -- Other ingredients* 32 Calcium Stearate** 2.0 Graphite, artificial** 1.0 *29.1% RDX, 0.9% wax, and 2.0% TNT. **Per cent added.	Molecular Weight: 48	
	Oxygen Balance: CO ₂ % -53 CO % -43	
	Density: gm/cc	Pressed 2.0
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 78 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 18 Sample Wt, mg 26	Boiling Point: °C	
	Refractive Index, n_{20}^D n_{25}^D n_{30}^D	
	Vacuum Stability Test: cc/40 Hrs, at 90°C ---- 100°C 0.67 120°C 135°C 150°C	
Friction Pendulum Test: Steel Shoe Sparks Fiber Shoe Unaffected	200 Gram Bomb Sand Test: Sand, gm 33.6	
Rifle Bullet Impact Test: Trials % Explosions Partial Burned Unaffected	Explosion Temperature: °C Seconds, 0.1 (no cap used) --- 1 --- 5 610 10 15 20	
	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate ---- Lead Azide 0.20 Tetryl 0.15	
	Ballistic Mortar, % TNT:	
	Trauzl Test, % TNT:	
	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
75°C International Heat Test: % Loss in 48 Hrs Discoloration, fumes, odor None	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
100°C Heat Test: % Loss, 1st 48 Hrs 0.22 % Loss, 2nd 48 Hrs 0.12 Explosion in 100 Hrs None		
Flammability Index:		
Hygroscopicity: %		
Volatility:		

<p>Fragmentation Test:</p> <p>90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments: For TNT For Subject HE</p> <p>3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments: For TNT For Subject HE</p> <p>Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc</p>	<p>Shaped Charge Effectiveness, TNT = 100:</p> <p>Glass Cones Steel Cones</p> <p>Hole Volume</p> <p>Hole Depth</p> <hr/> <p>Color: Gray powder mixture</p> <hr/> <p>Principal Uses: Small caliber antiaircraft projectiles</p> <hr/> <p>Method of Loading: Pressed</p> <hr/> <p>Loading Density: gm/cc At 30,000 psi ~ 2.0</p> <hr/> <p>Storage:</p> <p>Method Dry</p> <p>Hazard Class (Quantity-Distance) Class 9</p> <p>Compatibility Group Group I Bureau of Explosives Class A</p>
<p>Blast (Relative to TNT):</p> <p>Air: Peak Pressure Impulse Energy</p> <p>Air, Confined: Impulse</p> <p>Under Water: Peak Pressure Impulse Energy</p> <p>Underground: Peak Pressure Impulse Energy</p>	<p><u>Heat of:</u></p> <p>Combustion, cal/gm 4392 Explosion, cal/gm 709 Gas volume, cc/gm 208</p> <p><u>Performance Tests:</u> <u>20 mm T215E1 Projectile:</u></p> <p>NFOC Pressure Cube 43 APG Blast Cube 53</p> <p><u>Aviation Energy:</u></p> <p>kcal/mol Values not included Temp, °C due to erratic igni- Time to ignition, tion under conditions seconds of test.</p>

Composition: % Oxidizing agent ----- Aluminum, atomized 49.2 Cupric Oxide 19.7 Magnesium, atomized ----- Other ingredients* 29.6 Calcium Stearate ----- Graphite, artificial 1.5 *28.7% RDX coated, 0.9% wax. C/H Ratio	Molecular Weight: 43	
	Oxygen Balance: CO ₂ % -50 CO % -42	
	Density: gm/cc	
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 78 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 19 Sample Wt, mg 27	Boiling Point: °C	
	Refractive Index, n ₂₀ ^D n ₂₅ ^D n ₃₀ ^D	
	Vacuum Stability Test: cc/40 Hrs, at 90°C ----- 100°C 0.43 120°C 135°C 150°C	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	200 Gram Bomb Sand Test: Sand, gm 10.8	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate ----- Lead Azide 0.20 Tetryl 0.16	
	Ballistic Mortar, % TNT:	
Explosion Temperature: °C Seconds, 0.1 (no cap used) --- 1 --- 5 510 10 15 20	Trauzl Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs 0.02/10 gm Discoloration, fumes, odor None	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
100°C Heat Test: % Loss, 1st 48 Hrs 0.00 % Loss, 2nd 48 Hrs 0.00 Explosion in 100 Hrs None	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
Flammability Index:		
Hygroscopicity: % 30°C, 90% RH, two weeks 0.79		
Volatility:		

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Color: Gray powder mixture Principal Uses: Small caliber antiaircraft projectiles
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Method of Loading: Pressed Loading Density: gm/cc At 30,000 psi ~2.0 Storage: <div style="display: flex; justify-content: space-between;"> Method Dry </div> <div style="display: flex; justify-content: space-between;"> Hazard Class (Quantity-Distance) Class 9 </div> <div style="display: flex; justify-content: space-between;"> Compatibility Group Group I </div> <div style="display: flex; justify-content: space-between;"> Bureau of Explosives </div> <div style="display: flex; justify-content: space-between;"> Class A </div> Heat of: <div style="display: flex; justify-content: space-between;"> Combustion, cal/gm 4293 </div> <div style="display: flex; justify-content: space-between;"> Explosion, cal/gm 750 </div> <div style="display: flex; justify-content: space-between;"> Gas volume, cc/gm 204 </div> Activation Energy: <div style="display: flex; justify-content: space-between;"> kcal/mol Values not included </div> <div style="display: flex; justify-content: space-between;"> Temp, °C due to erratic igni- </div> <div style="display: flex; justify-content: space-between;"> Time to ignition, tion under conditions </div> <div style="display: flex; justify-content: space-between;"> seconds of test. </div>

Preparation:

The various ingredients used in the preparation of MOX explosives are coated separately as follows:

Dichromated Atomized Aluminum - Seventy-five grams of chemically pure grade sodium dichromate is dissolved in 1500 milliliters of water at 100°C under mechanical agitation. Six hundred grams of the atomized aluminum powder is added gradually (2 to 3 minutes) and stirring is continued for half an hour. The dichromated metal is filtered, washed with water (15 to 20 times) until the washings show only a slight cloudiness with silver nitrate. The water-wet product is then dried in an oven at 50°C. The dried material is hand-rolled to reduce any conglomerates, and blended before use.

Wax-Coated RDX - Eighteen grams of molten Be Square Special Wax (manufacturer's 180° to 185° Fahrenheit grade amber) is added to 582 grams of finely divided RDX (water precipitated from acetone solution) in a water slurry under mechanical agitation. The temperature of the wax-RDX slurry is maintained above the melting point of the wax (about 90°C). The stirring is continued for half an hour. After cooling to 50°C, the wax-coated RDX is recovered by filtration in a Büchner funnel and dried in air. The RDX thus coated and presumed to be 3% waxed RDX or a 97/3 RDX/wax mixture is hand-rolled to crush any conglomerates formed, and blended by hand before use.

TNT-Coated Barium Nitrate - Thirty grams of TNT in alcohol solution is added to 270 grams of barium nitrate in an alcohol slurry under agitation. The temperature of the TNT-barium nitrate mixture is maintained at 80°C and stirring is continued until most of the alcohol is evaporated. The coated material is spread in a thin layer on a tray to dry in air overnight. The barium nitrate thus coated with 10% TNT is reduced to an intimate mixture by hand-rolling and blending before use.

TNT-Coated Potassium Nitrate - The TNT-coated potassium nitrate is prepared by the same procedure as is used for coating barium nitrate.

RDX/TNT-Coated Ammonium Perchlorate - The ammonium perchlorate is coated by dissolving the appropriate weights of RDX and TNT in hot alcohol. After adding the ammonium perchlorate, the slurry is stirred until most of the solvent is evaporated. The treated ammonium perchlorate is spread on a tray to dry overnight. Agglomerates formed during the process are crushed by hand-rolling and blending the mixture before use.

TNT-Coated RDX - Sixty grams of molten TNT are added to a water slurry of 540 grams of finely divided RDX (water precipitated from acetone solution) under mechanical agitation. The temperature of the TNT-RDX slurry is maintained at about 90°C and stirring is continued for half an hour. After cooling to about 50°C, the TNT-coated RDX is recovered by filtration. The RDX thus treated, and presumed to be 10% coated or a 90/10 RDX/TNT mixture, is further blended by hand after rolling to crush any aggregates formed during the process.

The MOX explosive mixtures are prepared by blending the appropriate weights of the dry ingredients in a Patterson-Kelly twin-shell blender for at least 30 minutes.

Origin:

MOX type explosive mixtures were developed beginning in 1950 by National Northern, technical division of the National Fireworks Ordnance Corporation, West Hanover, Massachusetts.

References:⁴⁶

(a) A. O. Mirarchi and A. T. Wilson, Development of MOX Explosives for Improved 20 mm Ammunition, Navy Contract NOrd-10975, Task 1, National Fireworks Ordnance Corporation, First Yearly Summary, August 1950 to August 1951.

(b) A. T. Wilson, Development of MOX Explosives: Various Oxidants in MOX, First Progress Report NFOC-6, Navy Contract NOrd-12382, National Fireworks Ordnance Corporation, December 1952.

(c) A. O. Mirarchi, Properties of Explosives: Theory of the MOX Explosion, First Progress Report NFOC-10, Navy Contract NOrd-11393, National Fireworks Ordnance Corporation, December 1952.

(d) A. O. Mirarchi, Properties of Explosives: MOX Explosives in Various Atmospheres, First Progress Report NFOC-9, Navy Contract NOrd-11393, National Fireworks Ordnance Corporation, 1952.

(e) A. T. Wilson, Development of MOX Explosives: Composition Variations, First Progress Report NFOC-7, Navy Contract NOrd-12382, National Fireworks Ordnance Corporation, 1952.

(f) A. T. Wilson, Development of MOX Explosives: Various Oxidants in MOX, Second Progress Report NFOC-14, Navy Contract NOrd-13684, National Fireworks Ordnance Corporation, October 1953.

(g) A. W. O'Brien, Jr., C. W. Plummer, R. P. Woodburn and V. Philipchuk, Detonation Velocity Determinations and Fragment Velocity Determinations of Varied Explosive Systems and Conditions, National Northern Corporation Final Summary Report NNC-F-13, February 1958 (Contract DAI-19-020-501-ORD-(P)-58).

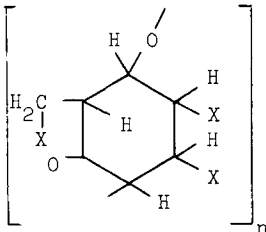
(h) P. Z. Kalanski, Air Blast Evaluation of MOX-2B Cased and Bare Charges, NAVORD Report No. 3755, 5 April 1956.

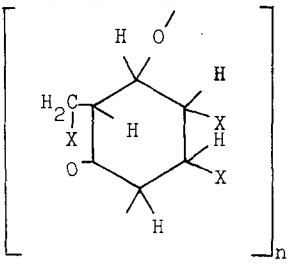
(i) Also see the following Picatinny Arsenal Technical Reports on MOX Explosives: 1935, 1969, 2204, 2205.

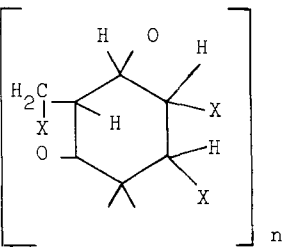
⁴⁶See footnote 1, page 10.

AMCP 706-177

Nitrocellulose, 12.6% N (NC)

Composition: % C 26.46 H 2.78 N 12.60 O 58.16 X=ONO ₂ C/H Ratio 0.23				Molecular Weight: (272.39) _n	
				Oxygen Balance: CO ₂ % -35 CO % 0.6	
				Density: gm/cc	
				Melting Point: °C Decomposes	
				Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 8 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 3 Sample Wt, mg 5				Boiling Point: °C	
				Refractive Index, n ₂₀ ^D n ₂₅ ^D n ₃₀ ^D	
Friction Pendulum Test: Steel Shoe Fiber Shoe				Vacuum Stability Test: cc/40 Hrs, at 90°C 0.17 100°C 1.0 120°C 16 hours 11.+ 135°C 150°C	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected				200 Gram Bomb Sand Test: Sand, gm 45.0	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 170 10 15 20				Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.10 Tetryl	
75°C International Heat Test: % Loss in 48 Hrs				Ballistic Mortar, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs				Trauzl Test, % TNT:	
Flammability Index:				Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
Hygroscopicity: % 30°C, 90% RH 3				Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
Volatility: 60°C, mg/cm ² /hr 0.0					

Composition: % C 25.29 H 2.52 N 13.45 O 58.74 X=ONO ₂ C/H Ratio 0.23			
		Molecular Weight:	(286.34) _n
		Oxygen Balance:	
		CO ₂ %	-29
		CO %	4.7
		Density: gm/cc	
		Melting Point: °C	Decomposes
		Freezing Point: °C	
		Boiling Point: °C	
		Refractive Index, n_{20}^D	
		n_{25}^D	
		n_{30}^D	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 9 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 3 Sample Wt, mg 5		Vacuum Stability Test: cc/40 Hrs, at 90°C 0.42 100°C 1.5 120°C 11.+ 135°C 150°C	
Friction Pendulum Test: Steel Shoe Fiber Shoe		200 Gram Bomb Sand Test: Sand, gm 49.0	
Rifle Bullet Impact Test: Trials % Explosions Partial Burned Unaffected		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.10 Tetryl	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 230 10 15 20		Ballistic Mortar, % TNT: 125	
75°C International Heat Test: % Loss in 48 Hrs		Trauzl Test, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs 0.3 % Loss, 2nd 48 Hrs 0.0 Explosion in 100 Hrs None		Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
Flammability Index:		Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc 1.20 Rate, meters/second 7300	
Hygroscopicity: % 30°C, 90% RH ~ 2			
Volatility: 60°C, mg/cm ² /hr 0.0			

Composition: % C 24.25 H 2.37 N 14.14 O 59.24 X=ONO ₂ C/H Ratio 0.23		Molecular Weight: (297.15) _n	
		Oxygen Balance: CO ₂ % -24 CO % 8	
		Density: gm/cc 1.65-1.70	
		Melting Point: °C Decomposes	
		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 8 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 3 Sample Wt, mg 5		Boiling Point: °C	
		Refractive Index, n ₂₀ ^D n ₂₅ ^D n ₃₀ ^D	
Friction Pendulum Test: Steel Shoe Fiber Shoe		Vacuum Stability Test: cc/40 Hrs, at 90°C 1.46 100°C 14 hours 11.+ 120°C 16 hours 11.+ 135°C 150°C	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected		200 Gram Bomb Sand Test: Sand, gm 52.3	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 10 15 20		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.10 Tetryl	
		Ballistic Mortar, % TNT:	
		Trauzl Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs		Plate Dent Test: Method Condition Confined Density, gm/cc Brissance, % TNT	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs		Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
Flammability Index:			
Hygroscopicity: % 30°C, 90% RH ~ 1			
Volatility: 60°C, mg/cm ² /hr 0.0			

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: White Principal Uses: Pyroxylin (12% N), blasting explosives; pyrocellulose (12.60% N), smokeless powder; guncotton (13.35% N minimum), propellants Method of Loading:																						
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Loading Density: gm/cc																						
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Storage: <div style="display: flex; justify-content: space-between;"> Method Wet (8% to 30% water) </div> <div style="display: flex; justify-content: space-between;"> Hazard Class (Quantity-Distance) Class 12 </div> <div style="display: flex; justify-content: space-between;"> Compatibility Group Group M (wet) </div> <div style="display: flex; justify-content: space-between;"> Exudation None </div> Heat of: <table style="width: 100%; border-collapse: collapse;"> <tr> <td>Combustion, cal/gm</td> <td>2409*</td> <td>2313**</td> <td>2228***</td> </tr> <tr> <td>Explosion, cal/gm</td> <td>855*</td> <td>965**</td> <td>1058***</td> </tr> <tr> <td>Gas Volume, cc/gm</td> <td>919*</td> <td>883**</td> <td>853***</td> </tr> <tr> <td>Formation, cal/gm</td> <td>617*</td> <td>561**</td> <td>513***</td> </tr> </table> <p style="margin-left: 40px;"> * 12.6% N ** 13.45% N *** 14.14% N </p> Vapor Pressure: <table style="width: 100%; border-collapse: collapse;"> <tr> <th style="text-align: center;"><u>°C</u></th> <th style="text-align: center;"><u>mm Mercury</u></th> </tr> <tr> <td style="text-align: center;">25</td> <td style="text-align: center;">0.00</td> </tr> <tr> <td style="text-align: center;">60</td> <td style="text-align: center;">0.00</td> </tr> </table>	Combustion, cal/gm	2409*	2313**	2228***	Explosion, cal/gm	855*	965**	1058***	Gas Volume, cc/gm	919*	883**	853***	Formation, cal/gm	617*	561**	513***	<u>°C</u>	<u>mm Mercury</u>	25	0.00	60	0.00
Combustion, cal/gm	2409*	2313**	2228***																				
Explosion, cal/gm	855*	965**	1058***																				
Gas Volume, cc/gm	919*	883**	853***																				
Formation, cal/gm	617*	561**	513***																				
<u>°C</u>	<u>mm Mercury</u>																						
25	0.00																						
60	0.00																						

<u>Solubility in Water, gm/100 gm, at:</u>	<u>12.6% N</u>	<u>13.45% N</u>	<u>14.0% N</u>
25°C	Insoluble	Insoluble	Insoluble
60°C	Insoluble	Insoluble	Insoluble
<u>Solubility, gm/100 gm, 25°C, in:</u>			
Ether	Insoluble	Insoluble	Insoluble
Alcohol	Very slight- ly soluble	Practically insoluble	Insoluble
2:1-Ether:Alcohol	Soluble	Slightly soluble (6%-11%)	Practically insoluble (1 + %)
Acetone	Soluble	Soluble	Soluble
<u>240-Hour Hydrolysis Test,</u> <u>% Nitric Acid</u>	1.22	1.03	

Preparation of Nitrocellulose from Cotton Linters:
(Laboratory Procedure)

Nitration: Second cut cotton linters, previously dried to a moisture content of less than 0.5%, are nitrated by immersion in mixed acid under the following conditions:

Ratio of Mixed Acid to cotton 55 to 1

Composition of Mixed Acid (approximate)

- a. for 12.6% N: H_2SO_4 63.5%, HNO_3 21%, H_2O 15.5%
- b. for 13.4% N: H_2SO_4 68%, HNO_3 22%, H_2O 10.0%

Temperature of acid at the start 34°C

Time of nitration 24 minutes

During the nitration period the mixture is turned over occasionally to keep the acid homogeneous. The mixture is then filtered on a Buchner funnel with suction for about three minutes and then drowned rapidly with strong hand stirring in at least 50 volumes of cold water. After the nitrocellulose has settled, most of the water is decanted and fresh water added. The nitrocellulose-water mixture is boiled and the acidity adjusted to 0.25% to 0.50% as H_2SO_4 . The sour boil is continued for at least 24 hours for pyrocellulose and at least 40 hours for gun-cotton. Additional boiling with changes of water are made in accordance with the governing specification (JAN-N-244).

Pulping: The nitrocellulose is then pulped in a laboratory Holland-type paper beater. Enough sodium carbonate is added to keep the reaction faintly alkaline to phenolphthalein. Pulping is continued to the desired degree of fineness.

Poaching: After washing the nitrocellulose from the beater, the mixture is filtered and the product boiled for 4 hours with fresh water while stirring mechanically. From time to time a little sodium carbonate solution is added to maintain the mixture faintly alkaline to phenolphthalein. The water is decanted and the boiling continued. According to the specification, the total boiling treatment with poaching is as follows:

- 4 hours boiling with or without sodium carbonate
- 2 hours boiling without sodium carbonate
- 1 hour boiling without sodium carbonate
- 1 hour boiling without sodium carbonate.

Each boil is followed by settling and change of water.

Washing: The nitrocellulose is then washed by mechanical agitation with water. A minimum of two washes are given. If a sample taken after the water washes gives a minimum test of 35 minutes in the 65.5°C Heat Test and 30 minutes in the 134.5°C Heat Test, the nitrocellulose is satisfactorily stabilized. Otherwise additional washes should be given.

Origin:

Cellulose occurs in nature. It is wood fiber, cell wall and the structural material of all plants. Cotton fiber is pure cellulose. Nitrocellulose was discovered about 1847 by C. F. Schonbein at Basel and R. Bottger at Frankfort-on-the-Main independently of each other when cotton was nitrated. T. J. Pelouze had nitrated paper earlier (1838) and was probably the first to prepare nitrocellulose.

Pyroxylin or collodion, which is soluble in a mixture of ether and ethanol, contains from 8% to 12% nitrogen. It is used in the manufacture of celluloid and in composite blasting explosives.

Pyrocellulose, a type of nitrocellulose of 12.6% nitrogen content, completely soluble in a mixture of 2 parts ether and one part ethanol, was developed by Mendeleev (1891-1895). This material, when colloided, formed the first smokeless powder for military use in the United States (1898).

Guncotton for military purposes today contains a minimum of 13.35% nitrogen. It is only slightly soluble in ether-ethanol, but completely soluble in acetone. Principal use is in flashless powders and as flame carriers. 14.14% N nitrocellulose represents a theoretical limit.

In the manufacture of propellants, there is used a mixture of pyrocellulose and guncotton (blended nitrocellulose) of 13.15% to 13.25% nitrogen content.

Destruction by Chemical Decomposition:

Nitrocellulose is decomposed by adding it, with stirring, to 5 times its weight of 10% sodium hydroxide heated to 70°C. Stirring is continued for 15 minutes after all the nitrocellulose has been added.

References:⁴⁷

- (a) See the following Picatinny Arsenal Technical Reports on Nitrocellulose:

⁴⁷See footnote 1, page 10.

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
10	41	72	13	4	125	86	167	8	19
390	101	332	33	24	475	576	327	198	29
420	231	402	43	114	485	586	407	208	69
660	351	422	133	174	495	796	717	278	169
730	551	542	233	194	555	916	787	388	279
960	831	572	253	334	705	1016	987	408	499
1020	851	652	273	374	965	1026	1187	588	659
1100	971	662	653	394	1065	1066	1197	718	669
1150	1031	752	673	724	1125	1206	1267	758	709
1190	1041	802	683	804	1135	1256	1297	778	739
1210	1071	952	773	894	1205	1276	1327	808	779
1240	1151	1012	793	1024	1265	1306	1407	838	809
1300	1201	1032	963	1054	1275	1316	1427	858	909
1320	1221	1142	1023	1074	1365	1516	1447	1058	1119
1350	1231	1242	1233	1084	1375	1556	1487	1228	1159
1410	1331	1282	1273	1174	1745	1616	1587	1238	1249
1430	1351	1362	1443	1274	1755	1786	1637	1248	1309
1490	1391	1392	1663	1304	1845	2056	1717	1348	1329
1580	1401	1642	1753	1314	1905		1817	1398	1349
1660	1421	1812	1813	1384	1915		1827	1478	1399
1810	1501	1852	1863	1394	1955		1847	1528	1439
1830	1541	1912	1873	1454			2107	1638	1449
1990	1681	1992	1973	1674			2137	1678	1619
2210	1691	2022		1754				1838	1799
	1731	2102		1814				1898	1809
	1781			1824				1918	1869
	1811			2144				2098	2119
	1831							2208	2189
	1841								
	1851								
	1931								
	1961								
	1991								
	2071								
	2101								
	2181								
	2201								

Composition: % C 15.9 $\begin{array}{c} \text{H}_2\text{C} - \text{ONO}_2 \\ \\ \text{HC} - \text{ONO}_2 \\ \\ \text{H}_2\text{C} - \text{ONO}_2 \end{array}$ H 2.2 N 18.5 O 63.4 C/H Ratio 0.109			Molecular Weight: $(\text{C}_3\text{H}_5\text{N}_3\text{O}_9)$ 227 Oxygen Balance: CO ₂ % 3.5 CO % 24.5 Density: gm/cc 25°C, Liquid 1.591 20°C, Liquid 1.596 Melting Point: °C Labile form 2.2 Stable form 13.2 Freezing Point: °C		
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 15 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 1 lb wt 1 Sample Wt, mg			Boiling Point: °C Decomposes 145 Refractive Index, n_{20}^D 1.4732 n_{25}^D 1.4713 n_{30}^D		
Friction Pendulum Test: Steel Shoe Explodes Fiber Shoe			Vacuum Stability Test: cc/40 Hrs, at 90°C cc/gm/6 hrs 1.6 100°C cc/gm/16 hrs 11+ 120°C 135°C 150°C		
Rifle Bullet Impact Test: Trials Explosions % 100 Partial 0 Burned 0 Unaffected 0			200 Gram Bomb Sand Test: Sand, gm Liquid method 51.5		
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Explodes 222 10 15 20			Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl		
75°C International Heat Test: % Loss in 48 Hrs			Ballistic Mortar, % TNT: (a) 140 Trauzl Test, % TNT: (b) 181		
100°C Heat Test: % Loss, 1st 48 Hrs 3.6 % Loss, 2nd 48 Hrs 3.5 Explosion in 100 Hrs None			Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT		
Flammability Index:			Detonation Rate: Confinement Glass Steel Condition Liquid Liquid Charge Diameter, in. 0.39 1.25 Density, gm/cc 1.6 1.6 Rate, meters/second 1600-1900 7700		
Hygroscopicity: % 30°C, 90% RH 0.06					
Volatility: 60°C, mg/cm ² /hr 0.11					

Booster Sensitivity Test: Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc	Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH, kcal/mol) Temperature Range, °C Phase		
	10 ^{17.3}	10 ^{19.2}	
	41.4	45.0	
	90-135	125-150	
	Liquid	Liquid	

Heat of: Combustion, cal/gm Explosion, cal/gm Gas Volume, cc/gm Formation, cal/gm Fusion, cal/gm Detonation, cal/gm	1616 1600 715 400 1486
--	--

Specific Heat: cal/gm/°C Liquid Solid	0.356 0.315
--	--------------------

Burning Rate: cm/sec

Thermal Conductivity: cal/sec/cm/°C

Coefficient of Expansion: Linear, %/°C Volume, %/°C
--

Hardness, Mohs' Scale:

Young's Modulus: E', dynes/cm² E, lb/inch² Density, gm/cc

Compressive Strength: lb/inch²

Vapor Pressure: °C mm Mercury °C mm Mercury	20 0.00025 30 0.00083 40 0.0024 50 0.0073	60 0.0188 70 0.043 80 0.098 90 0.23
--	--	--

Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bombs: Plate Thickness, inches 1 1¼ 1½ 1¾
--

Bomb Drop Test: T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete: Max Safe Drop, ft 500-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order 1000-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order
--

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Colorless Principal Uses: Propellant ingredient, demolition explosive ingredient, grenade burster ingredient Method of Loading: Loading Density: gm/cc
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method With acetone or other desensitizer, generally not stored Hazard Class (Quantity-Distance) Class 9 Compatibility Group Exudation
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Heat of Transition, cal/gm: <u>Transition:</u> <div style="display: flex; justify-content: space-between;"> Liquid → labile 5.2 </div> <div style="display: flex; justify-content: space-between;"> Labile → stable 28.0 </div> <div style="display: flex; justify-content: space-between;"> Liquid → stable 33.2 </div> <u>Hydrolysis, % Acid:</u> <div style="display: flex; justify-content: space-between;"> 10 days at 22°C < 0.002 </div> <div style="display: flex; justify-content: space-between;"> 5 days at 60°C 0.005 </div> <u>82.1°C KI Test:</u> <div style="display: flex; justify-content: space-between;"> Minutes 10+ </div>

Gas Evolved at Atmospheric Pressure, cc:

Sample Wt, gm	1.6	
Temperature, °C	65	75
Time, hours	20	40
Volume of gas, cc	nil	nil

Viscosity: (c)

<u>°C</u>	<u>Centipoises</u>
10	69.2
20	36.0
30	21.0
40	13.6
50	9.4
60	6.8

Fragmentation Test:

20 mm HE, Mark 1, Projectile, Total No.
of Fragments for:

Nitroglycerin	22
Tetranitromethane	17

Minimum Propagating Diameter: (d)

<u>% Dimethylphthalate in NG</u>	<u>Min. Propagating Diameter, inches</u>	<u>Maximum Diameter for 2 Failures in 2 Trials, inches</u>
0	(3/16 Cairns)	1/16
5	--	1/8
10	1/8	3/16
15	1/4	3/8
20	3/4	7/8
22.5	1	1-1/2
25	1.55	2

Sensitivity to Electrostatic Discharge, Joules (test condition, unconfined;
no value given for confinement): > 12.5

Solubility, grams of nitroglycerin/100 gm (%) of:

<u>Water</u>		<u>Alcohol</u>		<u>Trichlorethylene</u>		<u>Carbon Tetrachloride</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
15	0.16	0	37.5	Rm	22	Rm	2
20	0.18	20	54.0				
50	0.25						

Nitroglycerin (Liquid)

<u>Carbon Disulfide</u>		<u>gm/100 gm (%), at 25°C in</u>	
<u>°C</u>	<u>%</u>		
Ambient	1	Ether	∞
		2:1, Ether:Alcohol	> 100
		Acetone	∞

Soluble in all Proportions in:

Methanol	Phenol
Acetone	Pyridine
Ether	Xylene
Ethyl acetate	Nitrobenzene
Amyl acetate	p-Nitrotoluene
Methyl nitrate	Liquid DNT
Ethyl nitrate	Chloroform
Nitroglycol	Ethyl chloride
Tetranitrodiglycerine	Ethyl bromide
Acetic acid	Tetrachloroethylene
Benzene	Dichloroethylene
Toluene	Trimethyleneglycol Dinitrate

Solubility in NG, of:

<u>Alcohol</u>		<u>DNT</u>		<u>TNT</u>		<u>Water</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
0	3.4	20	35	20	30	25	0.06
20	5.4						
50	∞						

Preparation:

Glycerine is usually nitrated at 25°C, or below, by adding it very slowly to a well agitated mixture of nitric and sulfuric acids, e.g., 40/59.5/0.5, nitric acid/sulfuric acid/water, using an acid/glycerine ratio of approximately 6. Agitation of the reaction mixture is accomplished by use of compressed air. A rapid temperature rise, or appearance of red fumes, automatically requires dumping of the charge, immediately, into a drowning vessel filled with water. After all the glycerine has been added to the nitrator, agitation and cooling are continued until the temperature drops to about 15°C, and the charge is then run into a separator where the NG rises to the top, and is run off to the neutralizer. The nitroglycerin is washed first with water, then with sodium carbonate, and finally with water. The resultant NG when washed with water, produces washings which do not color phenolphthalein, and itself is neutral to litmus paper.

Origin:

Nitroglycerin was first prepared in 1846 or 1847 by Ascanio Sobrero, an Italian chemist (Mem Acad Torino (2) 10, 195 (1847)). For several years after this discovery, nitroglycerin attracted little interest as an explosive until Alfred Nobel in 1864 patented improvements in its manufacture and method of initiation (British Patent 1813). Nobel gave the name dynamite to mixtures of nitroglycerin and non-explosive absorbents, such as charcoal, siliceous earth or Kieselguhr (British Patent 1345 (1867)). Later developments led to gelatine dynamites, ammonia dynamites, and so called straight dynamites. The first propellants using nitroglycerin were called Ballistite (Nobel, British Patent 1471 (1888)) and Cordite (Abel and Dewar, British Patents 5614 and 11,664 (1889)).

Destruction by Chemical Decomposition:

Nitroglycerin is decomposed by adding it slowly to 10 times its weight of 18% sodium sulfide ($\text{Na}_2\text{S} \cdot 9\text{H}_2\text{O}$). Heat is liberated by this reaction; but this is not hazardous if stirring is maintained during the addition of nitroglycerin and continued until solution is complete.

References:⁴⁸

(a) A. H. Blatt, Compilation of Data on Organic Explosives, OSRD Report No. 2014, 29 February 1944.

(b) Ph. Naoum, Z ges Schiess-Sprengstoffw, pp. 181, 229, 267 (27 June 1932).

(c) Landolt - Bornstein, Physikalisch-Chemische Tabellen, 5th Ed. (1923).

International Critical Tables.

B. T. Fedoroff et al, A Manual for Explosive Laboratories, Vol I-IV, Lefax Society, Inc., Philadelphia, 1943, 1946.

(d) H. A. Strecker, Initiation, Propagation and Luminosity Studies of Liquid Explosives, OSRD Report No. 5609, 3 December 1945.

(e) Also see the following Picatinny Arsenal Technical Reports on Nitroglycerin:

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
620	511	652	233	454	1155	1206	817	768	69
660	551	672	343	494	1235	1456	837	1348	249
800	701	792	673	1024	1955	1496	1197	1398	579
1020	891	922	903	1074	2015	1556	1297	1738	709
1150	911	1142	1023	1084		1616	1637	1918	1349
1210	1031	1282	1443	1454		1786	1817	2098	1359
1410	1041	1362	1643	1524		1816	1847		2119
1620	1151	1542	1663	1624		1896			
1680	1191	1662	1863	1674		2056			
	1221	1692	1993	1754					
	1611	1742							
	1651	1752							
	1691	1992							
	1731								
	1781								
	1851								
	1931								
	2021								
	2181								
	2201								

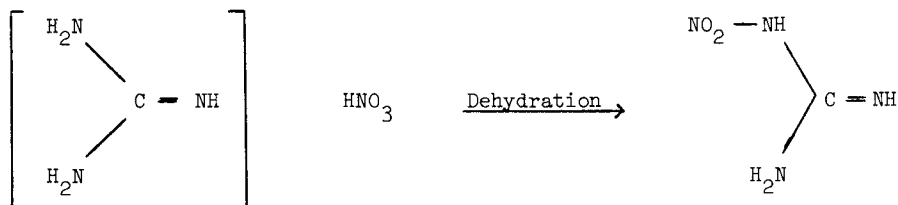
⁴⁸See footnote 1, page 10.

Composition: % C 11.5 H 3.9 N 53.8 O 30.8 C/H Ratio 0.038 <div style="text-align: center;"> $\begin{array}{c} \text{NH}_2 \\ \diagup \\ \text{HN}=\text{C} \\ \diagdown \\ \text{NH} \\ \\ \text{NO}_2 \end{array}$ </div>	Molecular Weight: $(\text{CH}_4\text{N}_4\text{O}_2)$ 104	
	Oxygen Balance: CO ₂ % -31 CO % -15.4	
	Density: gm/cc	Crystal 1.72
	Melting Point: °C 232	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 47 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 26 Sample Wt, mg 7	Boiling Point: °C	
	Refractive Index, n_{20}^D n_{25}^D n_{30}^D	
	Friction Pendulum Test: (e) Steel Shoe Unaffected Fiber Shoe Unaffected	
Rifle Bullet Impact Test: 5 Trials (e) Explosions % 0 Partial % 0 Burned % 0 Unaffected 100	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.37 120°C 0.44 135°C 150°C	
	200 Gram Bomb Sand Test: Sand, gm 36.0	
	Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 275 10 15 20	
75°C International Heat Test: % Loss in 48 Hrs 0.04 100°C Heat Test: % Loss, 1st 48 Hrs 0.18 % Loss, 2nd 48 Hrs 0.09 Explosion in 100 Hrs None	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.10	
	Ballistic Mortar, % TNT: (a) 104	
	Trauzl Test, % TNT: (b) 101	
Flammability Index: Hygroscopicity: % 30°C, 90% RH None Volatility: None	Plate Dent Test: (c) Method A Condition Pressed Confined No Density, gm/cc 1.50 Brisance, % TNT 95	
	Detonation Rate: (e) Confinement Condition Charge Diameter, in. Density, gm/cc 1.55 Rate, meters/second 7650	

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones Hole Volume Hole Depth																																		
	Color: Colorless																																		
	Principal Uses: Propellant composition ingredient, bursting charge ingredient																																		
	Method of Loading:																																		
	Loading Density: gm/cc At 3000 psi 0.95																																		
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation																																		
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Solubility, gm/100 gm (%), in: <table><tr><td></td><td>°C</td><td>%</td></tr><tr><td>Water</td><td>25</td><td>0.44</td></tr><tr><td></td><td>100</td><td>9.0</td></tr><tr><td>1.0 N Potassium Hydroxide</td><td>25</td><td>1.2</td></tr><tr><td>40% Sulfuric Acid</td><td>0</td><td>3.4*</td></tr><tr><td></td><td>25</td><td>8.0*</td></tr></table> * gm/100 cc solution Booster Sensitivity Test: <table><tr><td>Condition</td><td>(d) Pressed</td></tr><tr><td>Tetryl, gm</td><td>100</td></tr><tr><td>Wax, in. for 50% Detonation</td><td>0.67</td></tr><tr><td>Density, gm/cc</td><td>1.41</td></tr></table> Heat of: <table><tr><td>Combustion, cal/gm</td><td>1995</td></tr><tr><td>Explosion, cal/gm</td><td>721</td></tr><tr><td>Gas Volume, cc/gm</td><td>1077</td></tr><tr><td>Formation, cal/gm</td><td>227</td></tr></table>		°C	%	Water	25	0.44		100	9.0	1.0 N Potassium Hydroxide	25	1.2	40% Sulfuric Acid	0	3.4*		25	8.0*	Condition	(d) Pressed	Tetryl, gm	100	Wax, in. for 50% Detonation	0.67	Density, gm/cc	1.41	Combustion, cal/gm	1995	Explosion, cal/gm	721	Gas Volume, cc/gm	1077	Formation, cal/gm	227
	°C	%																																	
Water	25	0.44																																	
	100	9.0																																	
1.0 N Potassium Hydroxide	25	1.2																																	
40% Sulfuric Acid	0	3.4*																																	
	25	8.0*																																	
Condition	(d) Pressed																																		
Tetryl, gm	100																																		
Wax, in. for 50% Detonation	0.67																																		
Density, gm/cc	1.41																																		
Combustion, cal/gm	1995																																		
Explosion, cal/gm	721																																		
Gas Volume, cc/gm	1077																																		
Formation, cal/gm	227																																		

Preparation:

(Chemistry of Powder and Explosives, Davis)



Four hundred gms of dry guanidine nitrate is added in small portions to 500 cc concentrated sulfuric acid at 10°C, or below. As soon as all crystals have disappeared the milky solution is poured into 3 liters of ice-water, and allowed to stand until crystallization is complete. The product is filtered, rinsed with water, and recrystallized from about 4 liters of boiling water, yield about 90%.

Origin:

Nitroguanidine was first prepared in 1877 by Jousselein, but it was 1900 before it found use in propellant compositions. During World War I, nitroguanidine was used by the Germans as an ingredient of bursting charge explosives.

Destruction by Chemical Decomposition:

Nitroguanidine is decomposed by dissolving in 15 times its weight of 45% sulfuric acid at room temperature and warming the solution until gas is evolved. Heating is continued for one-half hour.

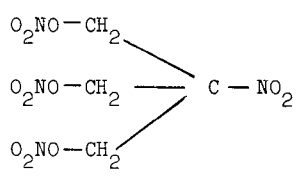
References:⁴⁹

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) Canadian Report, CE-12, 1 May-15 August 1941.
- (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (d) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Teteryl in Boosters, NOL Memo 10,303, 15 June 1949.
- (e) Departments of the Army and the Air Force TM 9-1910/TO 11A-1-34, Military Explosives, April 1955.

⁴⁹See footnote 1, page 10.

(f) Also see the following Picatinny Arsenal Technical Reports on Nitroguanidine:

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
1490	1391	1282	1183	1336	907	758	1439
	2181	1392	1423		2177		1749
	2201	2142	2193				

Composition: %			Molecular Weight: (C ₄ H ₆ N ₄ O ₁₁) 286	
C	16.8		Oxygen Balance:	
H	2.1		CO ₂ % 0.0	
N	19.6		CO % 22	
O	61.5			
C/H Ratio 0.126			Density: gm/cc 20°C 1.64	
Impact Sensitivity, 2 Kg Wt:			Melting Point: °C	
Bureau of Mines Apparatus, cm 25			Freezing Point: °C -39	
Sample Wt 20 mg			Boiling Point: °C	
Picatinny Arsenal Apparatus, in.			Refractive Index, n_D²⁰	
Sample Wt, mg			n _D ²⁵ 1.4896	
			n _D ³⁰ 1.4874	
Friction Pendulum Test:			Vacuum Stability Test:	
Steel Shoe			cc/40 Hrs, at	
Fiber Shoe			90°C	
			100°C	
			120°C	
			135°C	
			150°C	
Rifle Bullet Impact Test: Trials			200 Gram Bomb Sand Test:	
% 28			Sand, gm 0.2 gm sample absorbed	
Explosions			by 0.2 gm of kieselguhr 28	
Partials				
Burned				
Unaffected				
Explosion Temperature: °C			Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)			Minimum Detonating Charge, gm	
1			Mercury Fulminate	
5 Ignites 185			Lead Azide	
10			Tetryl	
15				
20				
75°C International Heat Test:			Ballistic Mortar, % TNT:	
% Loss in 48 Hrs			Trauzl Test, % TNT:	
100°C Heat Test:			Plate Dent Test:	
% Loss, 1st 48 Hrs			Method	
% Loss, 2nd 48 Hrs			Condition	
Explosion in 100 Hrs			Confined	
			Density, gm/cc	
			Brisance, % TNT	
Flammability Index:			Detonation Rate:	
			Confinement Glass (1 mm wall)	
Hygroscopicity: %			Condition Liquid	
			Charge Diameter, in. 0.39	
			Density, gm/cc 1.64	
Volatility:			Rate, meters/second 7860	
25°C, mg/cm ² /24 hrs 0.127 x 10 ⁻³				

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Yellow oil Principal Uses: Gelatinizing agent for nitrocellulose Method of Loading: Loading Density: gm/cc
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Liquid Hazard Class (Quantity-Distance) Compatibility Group Exudation
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	<u>Solubility:</u> Soluble in methyl and ethyl alcohols, acetone, ether, ethylenedichloride, chloroform and benzene. Insoluble in water, carbon disulphide, and petroleum ether. <u>Toxicity:</u> Slight, decidedly less than nitroglycerin. <u>Gelatinizing Action:</u> Slight on nitrocellulose. <u>82.2°C KI Test:</u> <div style="display: flex; justify-content: space-between;"> Minutes 2 </div>

Preparation:

A total of 675 gm 37% formalin is added to 150 gm nitromethane containing 2 gm potassium carbonate hemi-hydrate. The first 200 gm formalin is added slowly, keeping the temperature below 30°C, and then the heat of reaction is allowed to raise the temperature to 80°C, and the mixture then heated two hours at 90°C. The reaction mixture is then concentrated at reduced pressure and diluted, and this process repeated several times to remove formaldehyde. After the final concentration the cooled mixture is filtered and the crystalline product recrystallized from alcohol and then several times from ether and dried.

The nitrated product is then obtained by nitrating 50 gm nitroisobutylglycerol with 300 gm mixed acid (60/38/2, sulfuric acid/nitric acid/water) below 15°C for 1.5 hours.

Origin:

This explosive (also called Trimethylolnitromethane Trinitrate, Nitroisobutanetriol Trinitrate, Nitroisobutylglycerin Trinitrate and incorrectly but widely used Nitroisobutylglycerol Trinitrate) was first described in 1912 by Hofwimmer (Z ges Schiess - Sprengstoffw 7, 43 (1912)). Hofwimmer prepared the compound by the condensation of 3 moles of formaldehyde with 1 mole of nitromethane in the presence of potassium bicarbonate, the subsequent nitration of the product. The explosive can now be produced from coke, air, and natural gas.

References:⁵⁰

- (a) H. A. Aaronson, Study of Explosives Derived from Nitroparaffins, PATR No. 1125, 24 October 1941.
- (b) M. Aubry, Mém poudr, 25, 197-204 (1932-33); CA 27, 4083 (1933).
- (c) A. Stettbacher, Nitrocellulose 5, 159-62, 181-4, 203-6 (1934); CA 29, 1250 (1935).
- (d) W. de C. Crater, U.S. Patent 2,112,749 (March 1938); CA 32, 3964 (1938).
- (e) H. J. Hibshman, E. H. Pierson, and H. B. Haas, Ind Eng Chem 32, 427-9 (1940); CA 34, 3235 (1940).
- (f) A. Stettbacher, Z ges Schiess Sprengstoffw 37, 62-4 (1942); CA 38, 255 (1944).

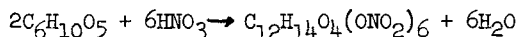
⁵⁰See footnote 1, page 10.

Composition: % Nitrostarch (12.50% N) 49 Barium Nitrate 40 Mononitronaphthalene 7 Paranitroaniline 3 Oil 1 C/H Ratio	Molecular Weight: 325	
	Oxygen Balance: CO ₂ % -19 CO % 8	
	Density: gm/cc	
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 21 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 8 Sample Wt, mg	Boiling Point: °C	
	Refractive Index, n_{20}^D n_{25}^D n_{30}^D	
	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 11+ 120°C 135°C 150°C	
Friction Pendulum Test: Steel Shoe Crackles, snaps Fiber Shoe Unaffected	200 Gram Bomb Sand Test: Sand, gm 39.5	
Rifle Bullet Impact Test: 10 Trials 8 Trials* % % Explosions 90 0 Partial 0 13 Burned 0 0 Unaffected 10 87 *Packed in paper	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.26 Lead Azide -- Tetryl --	
Explosion Temperature: °C Seconds, 0.1 (no cap used) -- 1 -- 5 Decomposes 195 10 15 20	Ballistic Mortar, % TNT: (a) 96	
75°C International Heat Test: % Loss in 48 Hrs 0.2	Trauzl Test, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs 0.3 % Loss, 2nd 48 Hrs 0.3 Explosion in 100 Hrs None	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
Flammability Index:	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
Hygroscopicity: % 30°C, 90% RH 2.1		
Volatility:		

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <table> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>		Glass Cones	Steel Cones	Hole Volume			Hole Depth		
	Glass Cones	Steel Cones								
Hole Volume										
Hole Depth										
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Color:									
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Principal Uses: Demolition, bursting charges, and priming compositions									
	Method of Loading: Hand tamped									
	Loading Density: gm/cc Apparent 0.92									
	Storage: <table> <tr> <td>Method</td> <td>Dry</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td>Class 9</td> </tr> <tr> <td>Compatibility Group</td> <td>Group I</td> </tr> <tr> <td>Exudation</td> <td>None</td> </tr> </table>	Method	Dry	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group	Group I	Exudation	None	
Method	Dry									
Hazard Class (Quantity-Distance)	Class 9									
Compatibility Group	Group I									
Exudation	None									
	120°C Heat Test: <table> <tr> <td></td> <td><u>Minutes</u></td> </tr> <tr> <td>Salmon Pink</td> <td>70</td> </tr> <tr> <td>Red Fumes</td> <td>255</td> </tr> <tr> <td>Explodes</td> <td>256</td> </tr> </table>		<u>Minutes</u>	Salmon Pink	70	Red Fumes	255	Explodes	256	
	<u>Minutes</u>									
Salmon Pink	70									
Red Fumes	255									
Explodes	256									

Preparation: (b)

The nitration of starch proceeds with the formation of hexanitro starch according to the following equation:



Tapioca starch is considered the best for nitration purposes, although other starches give fairly stable products. The starch, pretreated to remove oils, fats and water soluble impurities, is dried and screened. Feeding of the dried starch into stainless steel nitrators containing mixed acid (62%-63% HNO_3 and 37%-38% H_2SO_4) is done slowly with constant agitation of the mixture. The heat evolved must be controlled by cooling coils. The nitrated starch is separated from the spent acid, washed with a large amount of water and centrifuged. Final drying is on trays heated to 35°-40°C with air. This product is so sensitive even a static discharge might cause explosion.

Nitrostarch demolition explosives contain a high percentage of nitrostarch, an oxidizing agent, mineral oil, a stabilizer and/or other ingredients.

Origin:

Nitrostarch was first prepared in 1833 by Branconnot, who called it xyloidine (Ann chim phys [2] 52, 290 (1833)). T. J. Pelouze studied xyloidine further and reported its explosive properties (Compt rend 7, 713 (1838)). It found military use in the United States during World Wars I and II as blasting explosives and as an ingredient of bursting charges and priming compositions.

References:⁵¹

(a) W. R. Tomlinson, Jr., Physical and Explosive Properties of Military Explosives, PATR No. 1372, 29 November 1943.

(b) G. D. Clift and B. T. Fedoroff, A Manual for Explosives Laboratories, Vol I, Lefax Society, Inc., Philadelphia (1942).

(c) Also see the following Picatinny Arsenal Technical Reports on Nitrostarch Explosives:

<u>1</u>	<u>2</u>	<u>4</u>	<u>7</u>	<u>8</u>	<u>9</u>
1611	782	1034	1117	838	1269
	2032			848	

⁵¹See footnote 1, page 10.

Octol, 70/30

Composition: % HMX 70 TNT 30 C/H Ratio	Molecular Weight: 265	
	Oxygen Balance: CO ₂ % -38 CO % -7.5	
	Density: gm/cc	Cast 1.80
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg 18 26	Boiling Point: °C	
	Refractive Index, n_{20}^D n_{25}^D n_{30}^D	
	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 0.37 135°C 150°C	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	200 Gram Bomb Sand Test: Sand, gm Exploratory 58.4	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.30 Tetryl	
	Ballistic Mortar, % TNT: 115	
	Trauzl Test, % TNT:	
	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
	Detonation Rate: Confinement None Condition Cast Charge Diameter, in. 1.0 Density, gm/cc 1.80 Rate, meters/second 8377	
Explosion Temperature: °C Seconds, 0.1 (no cap used) --- 1 5 Flames erratically 335 10 15 20		
75°C International Heat Test: % Loss in 48 Hrs		
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs		
Flammability Index:		
Hygroscopicity: %		
Volatility:		

Booster Sensitivity Test: Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc	Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH , kcal/mol) Temperature Range, °C Phase
Heat of: Combustion, cal/gm 2722 Explosion, cal/gm 1074 Gas Volume, cc/gm 847 Formation, cal/gm ---- Fusion, cal/gm	Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bombs: Plate Thickness, inches 1 1¼ 1½ 1¾
Specific Heat: cal/gm/°C	Bomb Drop Test: T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete: Max Safe Drop, ft 500-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order 1000-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order
Burning Rate: cm/sec	
Thermal Conductivity: cal/sec/cm/°C	
Coefficient of Expansion: Linear, %/°C Volume, %/°C	
Hardness, Mohs' Scale:	
Young's Modulus: E', dynes/cm ² E, lb/inch ² Density, gm/cc	
Compressive Strength: lb/inch ² 1510 See below	
Vapor Pressure: °C mm Mercury Compressive Strength: lb/inch ² * Average (10 tests) 1510 High 1740 Low 1330	Ultimate Deformation: % Average (10 tests) 2.26 High 2.58 Low 1.97

*Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.

<p>Fragmentation Test:</p> <p>90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments: For TNT For Subject HE</p> <p>3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments: For TNT For Subject HE</p> <p>Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc</p>	<p>Shaped Charge Effectiveness, TNT = 100:</p> <p>Glass Cones Steel Cones</p> <p>Hole Volume</p> <p>Hole Depth</p> <hr/> <p>Color: Buff</p> <hr/> <p>Principal Uses: HE projectile and bomb filler</p> <hr/> <p>Method of Loading: Cast</p> <hr/> <p>Loading Density: gm/cc 1.80</p> <hr/> <p>Storage:</p> <p>Method Dry</p> <p>Hazard Class (Quantity-Distance) Class 9</p> <p>Compatibility Group Group I</p> <p>Exudation</p> <hr/> <p>Work to Produce Rupture: ft-lb/inch³ *</p> <p>Average (10 tests) 1.55</p> <p>High 1.87</p> <p>Low 1.10</p> <p>Efflux Viscosity, Saybolt Seconds: 5.9</p>
<p>Blast (Relative to TNT):</p> <p>Air: Peak Pressure Impulse Energy</p> <p>Air, Confined: Impulse</p> <p>Under Water: Peak Pressure Impulse Energy</p> <p>Underground: Peak Pressure Impulse Energy</p>	<p>*Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.</p>

Octol, 70/30

Effect of Altitude, Charge Diameter and Degree of Confinement on Detonation Velocity*
(Reference b)

<u>Explosive</u>	<u>Simulated Altitude, Feet</u>	<u>One-Inch Column</u>		<u>Two-Inch Column</u>	
		<u>Confined</u> m/s	<u>Unconfined</u> m/s	<u>Confined</u> m/s	<u>Unconfined</u> m/s
70/30, RDX/TNT; density, gm/cc 1.62	Ground	7900	8100	7660	8030
	30,000	8020	8120	7900(4)	7800
	60,000	8040	8140	8010	7950
	90,000	8060	7980	8010	7710
	Average	8005	8085	7895	7873
70/30, HMX/TNT; density, gm/cc 1.61	Ground	7960	7900(4)	7870	7640(4)
	30,000	8050	8060	7930	7710
	60,000	8020	7930	7890	7650
	90,000	7950	8000	7940	7650
	Average	7995	7973	7908	7663

*70/30 Octol confined charge in 1/4" steel tube, AISI 1015 seamless, 1" diameter 18" long, and 2" diameter 7" long. All means were determined from sets of five values unless otherwise indicated by (). A 26 gm tetra booster was used to initiate each charge.

Average Fragment Velocities at Various Altitudes* (g)

<u>Explosive</u>	<u>Charge Diameter, Inches</u>	<u>Simulated Altitude, Feet</u>			
		<u>Ground</u> m/s	<u>30,000</u> m/s	<u>60,000</u> m/s	<u>90,000</u> m/s
70/30, RDX/TNT	1	3415	3672	3666	3685
	2	4647	5192	5236	6011
70/30, HMX/TNT	1	3366	3680	4014	3617
	2	4703	5464	6089	6111

*Outside diameter 2.54"; inside diameter 2.04"; length 7".

Tensile Strength:*

	lb/inch ²
Average (8 tests)	169
High	204
Low	128

*Test specimen as per Picatinny Arsenal sketch XL-076B, at 21°C.

Modulus of Elasticity:*

	lb/inch ²
Average (10 tests)	73,200
High	79,300
Low	63,000

*Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.

Setback Sensitivity Test: (a)

Critical Pressure	92,000 psi*
Density, gm/cc	1.72

*Pressure below which no initiation is obtained and above which an increasing percentage of initiations can be expected as the setback pressure increases.

Pit Fragmentation Test:

105 mm M1 HE Projectile:

Weight Group, grains	No. of Fragments
1/2 - 2	1297
2 - 5	665
5 - 10	497
10 - 25	661
25 - 50	471
50 - 75	247
75 - 150	322
150 - 750	295
750 - 2500	12
Total Number	4467

Composition: % HMX 75 TNT 25 C/H Ratio	Molecular Weight: 276	
	Oxygen Balance: CO ₂ % -35 CO % -6.3	
	Density: gm/cc	Cast 1.81
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm -- Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 17 Sample Wt, mg 25	Boiling Point: °C	
	Refractive Index, n ₂₀ ^D n ₂₅ ^D n ₃₀ ^D	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C ---- 100°C ---- 120°C 0.39 135°C 150°C	
	200 Gram Bomb Sand Test: Sand, gm Exploratory 62.1	
Rifle Bullet Impact Test: 10 Trials % 3/16" Steel 1/8" Al Explosions 70 70 Partials -- -- Burned -- -- Unaffected 30 30	Explosion Temperature: °C Seconds, 0.1 (no cap used) --- 1 --- 5 Flames erratically 350 10 15 20	
	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate ---- Lead Azide 0.30 Tetryl ----	
75°C International Heat Test: % Loss in 48 Hrs	Ballistic Mortar, % TNT: 116	
	Trauzl Test, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
	Detonation Rate: Confinement None Condition Cast Charge Diameter, in. 1.0 Density, gm/cc 1.81 Rate, meters/second 8643	
Flammability Index:		
Hygroscopicity: %		
Volatility:		

Booster Sensitivity Test: Condition Tetryl, gm Wax, in. for 50 % Detonation Wax, gm Density, gm/cc	Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH, kcal/mol) Temperature Range, °C Phase
Heat of: Combustion, cal/gm 2676 Explosion, cal/gm 1131 Gas Volume, cc/gm 830 Formation, cal/gm Fusion, cal/gm 29.4* *Calculated for 76.9% HMX, 23.1% TNT.	Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bombs: Plate Thickness, inches 1 1¼ 1½ 1¾
Specific Heat: cal/gm/°C ** -79°C 0.200 -80°C to +80°C 0.240 33°C to 74°C 0.245 90°C to 150°C 0.323 **Determined for 76.9% HMX, 23.1% TNT.	Bomb Drop Test: T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete: Max Safe Drop, ft 500-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order 1000-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order
Burning Rate: cm/sec	
Thermal Conductivity: cal/sec/cm/°C	
Coefficient of Expansion: Linear, %/°C Volume, %/°C	
Hardness, Mohs' Scale:	
Young's Modulus: E', dynes/cm² E, lb/inch² Density, gm/cc	Ultimate Deformation: % Average (10 tests) 2.43 High 2.89 Low 2.04
Compressive Strength: lb/inch² 1340 See below	
Vapor Pressure: °C mm Mercury	
Compressive Strength: lb/inch² *** Average (10 tests) 1340 High 1560 Low 1040	

***Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Buff Principal Uses: HE projectile and bomb filler Method of Loading: Cast Loading Density: gm/cc 1.81
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	<div style="border: 1px solid black; padding: 5px;"> Work to Produce Rupture: ft-lb/inch³ * Average (10 tests) 1.31 High 1.57 Low 1.07 Efflux Viscosity, Saybolt Seconds: 9.0 </div> *Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.

Fragment Velocity Test: (a)M26 Hand Grenade:

Explosive	Average Fragment Velocity, ft/sec over 1st 6 feet
Composition B	4948
75/25 Cyclotol	4908
75/25 Octol	5124

Tensile Strength:*

	lb/inch ²
Average (10 tests)	266
High	330
Low	226

*Test specimen as per Picatinny Arsenal sketch XL-076B, at 21°C.

Modulus of Elasticity:*

	lb/inch ²
Average (10 tests)	62,100
High	75,900
Low	45,200

*Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.

Setback Sensitivity Test: (a)

Critical Pressure	76,000 psi*
Density, gm/cc	1.80

*Pressure below which no initiation is obtained and above which an increasing percentage of initiations can be expected as the setback pressure increases.

Pit Fragmentation Test: (a)105 mm ML HE Projectile:

Weight Group, grains	No. of Fragments
1/2 - 2	1611
2 - 5	777
5 - 10	535
10 - 25	719
25 - 50	480
50 - 75	246
75 - 150	339
150 - 750	293
750 - 2500	8
Total Number	5008

Preparation:

Water-wet HMX is added slowly to molten TNT in a steam-jacketed kettle at a temperature of 100°C. The mixture is heated and stirred until all moisture is evaporated. The composition is cooled to a satisfactory pouring temperature and cast directly into ammunition components or prepared in the form of chips to be stored for later use.

References:⁵²

(a) 1st Indorsement from Chief, Explosives Development Section, to Chief, Explosives Research Section, Picatinny Arsenal, dated 12 May 1958. Subject: "Properties of Octols and HTA-3."

(b) A. W. O'Brien, Jr., C. W. Plummer, R. P. Woodburn and V. Philipchuk, Detonation Velocity Determinations and Fragment Velocity Determinations of Varied Explosive Systems and Conditions, National Northern Corporation Final Summary Report NNC-F-13, February 1958 (Contract DAI-19-020-501-ORD-(P)-58).

⁵²See footnote 1, page 10.

PB-RDX

AMCP 706-177

Composition:		Molecular Weight:		245
%		Oxygen Balance:		
RDX	90	CO ₂ %		-62
Polystyrene (unmodified)	8.5	CO %		-18
Diocetylphthalate	1.5	Density: gm/cc		Unpressed 0.81
		Pellet pressed at 30,000 psi		1.62
C/H Ratio		Melting Point: °C		
		Freezing Point: °C		
Impact Sensitivity, 2 Kg Wt:		Boiling Point: °C		
Bureau of Mines Apparatus, cm	Unpressed 28	Refractive Index, n_{20}^D		
Sample Wt 20 mg		n_{25}^D		
Picatinny Arsenal Apparatus, in.	15	n_{30}^D		
Sample Wt, mg	20	Vacuum Stability Test:		
Friction Pendulum Test:		cc/40 Hrs, at		
Steel Shoe	Unaffected	90°C		----
Fiber Shoe	Unaffected	100°C		----
Rifle Bullet Impact Test: 10 Trials *		120°C		0.41
	%	135°C		
Explosions	10	150°C		
Partials	90	200 Gram Bomb Sand Test:		
Burned	0	Sand, gm		
Unaffected	0	Sensitivity to Initiation:		
Explosion Temperature: °C		Minimum Detonating Charge, gm		
Seconds, 0.1 (no cap used)	---	Mercury Fulminate		
1	---	Lead Azide		
5 Smokes	275	Tetryl		
10		Ballistic Mortar, % TNT:		
15		Trauzl Test, % TNT:		
20		Plate Dent Test:		
75°C International Heat Test:		Method		
% Loss in 48 Hrs		Condition		
100°C Heat Test:		Confined		
% Loss, 1st 48 Hrs	0.00	Density, gm/cc		
% Loss, 2nd 48 Hrs	0.00	Brisance, % TNT		
Explosion in 100 Hrs	None	Detonation Rate:		
Flammability Index:		Confinement		
Hygroscopicity: %		Condition		
		Charge Diameter, in.		
		Density, gm/cc		
		Rate, meters/second		
* Test procedure described in PATR No. 2247, May 1956.				

Booster Sensitivity Test: Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc	Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH , kcal/mol) Temperature Range, °C Phase
Heat of: Combustion, cal/gm 3027 Explosion, cal/gm 983 Gas Volume, cc/gm Formation, cal/gm Fusion, cal/gm	Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bombs: Plate Thickness, inches 1 1¼ 1½ 1¾
Specific Heat: cal/gm/°C	Bomb Drop Test: T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete: Max Safe Drop, ft 500-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order 1000-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order
Burning Rate: cm/sec	
Thermal Conductivity: cal/sec/cm/°C	
Coefficient of Expansion: Linear, %/°C Volume, %/°C	
Hardness, Mohs' Scale:	
Young's Modulus: See below E', dynes/cm² E, lb/inch² Density, gm/cc	
Compressive Strength: lb/inch² 2403 2149 Percent 8.9 13.1	
Vapor Pressure: °C mm Mercury Young's Modulus: * (a) <u>Temperature</u> E, lb/inch² (avg of 5) <u>Ambient</u> 95°C Density, gm/cc 39,953 34,831 1.60 1.57	

*Pellets (Lot OAC-596-55) 0.750 inch diameter by 0.750 inch long, pressed at 30,000 psi with 30-second dwell.

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: White Principal Uses: High mechanical strength explosive																											
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Method of Loading: Pressed <div style="display: flex; justify-content: space-between;"> <div> Loading Density: gm/cc 0 10 20 30 1.10 1.49 1.59 1.62 </div> <div> Pressed, psi x 10³ </div> </div>																											
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation None Rockwell Hardness, "R" Scale: (a) <u>1/2 inch diameter Penetrator, 60 Kg Load:</u> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: center;">Pellet No.*</th> <th style="text-align: center;">Specific Gravity</th> <th style="text-align: center;">Hardness</th> </tr> </thead> <tbody> <tr><td style="text-align: center;">1</td><td style="text-align: center;">1.624</td><td style="text-align: center;">84</td></tr> <tr><td style="text-align: center;">2</td><td style="text-align: center;">1.623</td><td style="text-align: center;">90</td></tr> <tr><td style="text-align: center;">3</td><td style="text-align: center;">1.611</td><td style="text-align: center;">84</td></tr> <tr><td style="text-align: center;">4</td><td style="text-align: center;">1.600</td><td style="text-align: center;">80</td></tr> <tr><td style="text-align: center;">5</td><td style="text-align: center;">1.590</td><td style="text-align: center;">75</td></tr> <tr><td style="text-align: center;">6</td><td style="text-align: center;">1.571</td><td style="text-align: center;">73</td></tr> <tr><td style="text-align: center;">7</td><td style="text-align: center;">1.548</td><td style="text-align: center;">62</td></tr> <tr><td style="text-align: center;">8</td><td style="text-align: center;">1.524</td><td style="text-align: center;">49</td></tr> </tbody> </table> *Pellets (Lot HOL-E-93) were 1-1/2 inches in diameter and 3/4 inch high.	Pellet No.*	Specific Gravity	Hardness	1	1.624	84	2	1.623	90	3	1.611	84	4	1.600	80	5	1.590	75	6	1.571	73	7	1.548	62	8	1.524	49
Pellet No.*	Specific Gravity	Hardness																										
1	1.624	84																										
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5	1.590	75																										
6	1.571	73																										
7	1.548	62																										
8	1.524	49																										

PB-RDX

Sensitivity of PB-RDX and 98/2 RDX/Stearic Acid
Pellets* to Initiation by Type II Special Blasting Caps (a)

Pellets	Gap (Distance From Base of Cap to Pellet), Inches						
	0.250	0.300	0.350	0.400	0.450	0.500	0.750
<u>PB-RDX with Pellet Density</u> <u>1.55 gm/cc</u>							
No. of Trials	1	8	5	6	2	1	1
Average Depth of Plate Indentation, inches **	0.082	0.090	0.087	0.080	0.080	—	—
No. of Failures	0	1	3	4	1	1	1
<u>PB-RDX with Pellet Density</u> <u>1.60 gm/cc</u>							
No. of Trials	3	8	9	4	3	5	2
Average Depth of Plate Indentation, inches **	0.090	0.089	0.087	0.084	0.087	0.075	—
No. of Failures	0	0	2	3	2	3	2
<u>98/2 RDX/Stearic Acid With</u> <u>Pellet Density 1.63 gm/cc</u>							
No. of Trials	5	3	5	5	5	5	5
Average Depth of Plate Indentation, inches **	0.109	0.096	0.095	0.092	0.097	0.087	—
No. of Failures	0	1	0	3	4	4	5

* Pellets 0.92 inch diameter, 0.375 inch height.

** Mild steel plate 5" x 5" x 1".

Performance of PB-RDX as Booster: (b, d)

Ten 2.75 inch HEAT M1 Rocket Heads were unaffected in performance by storage at 71°C for 28 days. Thus, PB-RDX was not desensitized by contact with TNT-bearing explosives. Teteryl, similarly used, becomes desensitized when stored in bursting charges at elevated temperatures.

In addition, 108 modified M307A1 57 mm projectiles were fired for performance against armor. Each round contained a PB-RDX booster pellet. There was no evidence in these firings that the projectiles were inadequately boosted.

PB-RDXPreparation:

The purchase description sheet for polystyrene-bonded RDX (X-PA-PD-1088, 25 October 1956) requires that the PB-RDX shall be a mixture of RDX, coated and surrounded by a homogeneous mixture of polystyrene and dioctylphthalate. The specified percentage of RDX shall consist of a mixture of 75% Type B, Class A RDX and 25% Type B, Class E RDX. The granulation of the unpressed composition shall be as follows:

Through U. S. Standard Sieve No.	Minimum %	Maximum %
6	100	--
12	60	--
20	--	2
35	--	0

Two methods have been reported for the preparation of PB-RDX (Reference: Los Alamos Scientific Laboratory, Contract W-7405-Eng 36 with U.S. Atomic Energy Commission, Report No. LA-1448). The earlier method employed a Baker-Perkins type mixer to blend the components. This procedure gave a product with good pressing characteristics. However, the molding composition was nonuniform in granulation and tended to be dusty. The slurry method of PB-RDX preparation gave a product which was uniform, free-flowing and dustless. In addition, PB-RDX granulated by the slurry method exhibited satisfactory drying, handling and pressing characteristics.

The final procedure incorporating the better features found from the study of such variables as solvents, solvent/plastic ratios, lacquer addition and temperature, agitation, RDX particle size distribution, dispersants and rosin additive, was as follows (Reference c):

Forty-two and five-tenths grams (42.5 gm) of polystyrene and 8 cc dioctylphthalate were dissolved in 200 cc toluene in a lacquer dissolver. Steam was introduced into the jacket until the temperature reached 65°C. The lacquer was agitated constantly until it was ready to be added to the granulator. This lacquer contained a 1:4 ratio of plastic-plasticizer to toluene.

Four hundred and fifty grams (450 gm) of RDX and 4500 grams of H₂O (ratio 1:10) were added to the granulator. The agitator was set for 400 rpm and the temperature was raised to 75°C by introducing steam into the jacket. The temperature differential between the lacquer solution and the RDX/water slurry was 5° to 10°C.

The lacquer solution was poured through the charging funnel into the granulator. As soon as the lacquer was added, a solution of gelatin in water was added, and the mixture was agitated until the lacquer was well dispersed in the RDX slurry (approximately 5 minutes). Granulation took place at this point. Steam was introduced again into the jacket to distill the solvent until the temperature reached 98°C. Cooling water was then run into the jacket to cool the batch to 40°C. The coated material from the granulator was collected on a Buchner funnel and dried in a tray at 70°C for 24 hours. Temperatures below 70°C did not furnish enough heat, but a temperature of 80°C produced stickiness and caking of PB-RDX.

Origin:

An explosive consisting of RDX coated with polystyrene plasticized with dioctylphthalate was initially developed in 1952 for the Atomic Energy Commission by Los Alamos Scientific Laboratory of the University of California (Contract W-7405-Eng 36 with U. S. Atomic Energy

Commission, Report No. LA-1448). The specific formulation of 90/8.5/1.5 RDX/polystyrene/dioctylphthalate was subsequently standardized by Los Alamos. This explosive, originally designated PBX, has been redesignated PB-RDX. The detailed requirements for the present polystyrene-bonded RDX(PB-RDX) are given in purchase description X-PA-PD-1088, 25 October 1956.

References:⁵³

(a) B. J. Zlotucha, T. W. Stevens and C. E. Jacobson, Characteristics of Polystyrene-Bonded RDX(PB-RDX), PATR No. 2497, April 1958.

(b) A. J. Pascazio, The Suitability of a Bare PBX Booster Pellet in the 2.75 Inch M1 HEAT Rocket Head, PATR No. 2271, November 1955.

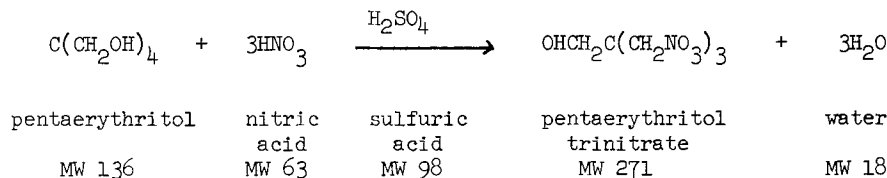
(c) J. L. Vermillion and R. C. Dubberly, Plastic-Bonded RDX, Its Preparation by the Slurry Method, Holston Defense Corporation, Control No. 20-T-16 Series A (PAC 1081), 5 March 1953.

(d) C. J. Eichinger, Report on Cartridge HEAT 57 mm M307A1 (Mod) with Modified Copper Liner, Aberdeen Proving Ground, Development and Proof Services, First Report on OC Project TA3-5204, October 1957.

⁵³See footnote 1, page 10.

Composition: % C 22.1 H 3.3 N 15.5 O 59.1 C/H Ratio 0.141 <div style="text-align: center;"> $\begin{array}{c} \text{CH}_2\text{ONO}_2 \\ \\ \text{HOCH}_2 - \text{C} - \text{CH}_2\text{ONO}_2 \\ \\ \text{CH}_2\text{ONO}_2 \end{array}$ </div>	Molecular Weight: ($\text{C}_5\text{H}_9\text{N}_3\text{O}_{10}$) 271
	Oxygen Balance: CO ₂ % -27 CO % 3
	Density: gm/cc 1.54
	Melting Point: °C 26 to 28
	Freezing Point: °C
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 5 to 10 Sample Wt, mg 38	Boiling Point: °C 4 mm Hg Decomposes 130
	Refractive Index, n_{20}^D n_{25}^D n_{30}^D
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C ---- 100°C 2.54 to 5.69 120°C 135°C 150°C
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 10 15 20	200 Gram Bomb Sand Test: Sand, gm
	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl
75°C International Heat Test: % Loss in 48 Hrs	Ballistic Mortar, % TNT:
	Trauzl Test, % TNT:
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT
Flammability Index:	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second
Hygroscopicity: %	
Volatility:	

<p>Fragmentation Test:</p> <p>90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments: For TNT For Subject HE</p> <p>3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments: For TNT For Subject HE</p>	<p>Shaped Charge Effectiveness, TNT = 100:</p> <p>Glass Cones Steel Cones</p> <p>Hole Volume</p> <p>Hole Depth</p>								
<p>Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc</p>	<p>Color: White</p>								
<p>Blast (Relative to TNT):</p> <p>Air: Peak Pressure Impulse Energy</p> <p>Air, Confined: Impulse</p> <p>Under Water: Peak Pressure Impulse Energy</p> <p>Underground: Peak Pressure Impulse Energy</p> <p><u>Absolute Viscosity, poises:</u></p> <table border="0"> <tr> <td>Temp, 17°C</td><td>14.8</td></tr> <tr> <td>23°C</td><td>4.8</td></tr> <tr> <td>28°C</td><td>3.0</td></tr> <tr> <td>38°C</td><td>1.2</td></tr> </table>	Temp, 17°C	14.8	23°C	4.8	28°C	3.0	38°C	1.2	<p>Principal Uses: Explosive, propellant or igniter ingredient</p>
Temp, 17°C	14.8								
23°C	4.8								
28°C	3.0								
38°C	1.2								
	<p>Method of Loading:</p>								
	<p>Loading Density: gm/cc</p>								
<p>Heat of:</p> <p>Explosion, cal/gm</p>	<p>Storage:</p> <p>Method Dry</p> <p>Hazard Class (Quantity-Distance)</p> <p>Compatibility Group</p> <p>Exudation None</p> <p>PETRIN esters are listed in reference (b) and most of these esters have been shown to have explosive properties.</p> <p>An infrared spectrophotometric procedure was developed for the determination of the acetone content of PETRIN (ref c). A 2.5 gm sample of PETRIN is dissolved in chloroform and the volume increased to 25 milliliters in a volumetric flask. The acetone content of the PETRIN solution is determined by its infrared absorption at 5.82μ in a 0.5 mm cell. A double beam method is used with a reference cell containing chloroform and acetone-free PETRIN. The quantity of the latter must be carefully adjusted to give a good balance between the test sample and reference cells for the strong PETRIN peak at 6.02μ maximum.</p> <p>1204</p>								

Preparation:

The earliest procedure used for the manufacture of PETRIN was that developed at Alleghany Ballistics Laboratory. In this process, called the "A process," 80% HNO₃ and the solid pentaerythritol were charged to the reactor and 80% H₂SO₄ was added slowly at a rate to permit control of temperature at 0° to 5°C. This mixture was held for a 2-1/2-hour reaction period, then drowned in water and filtered to give a cake containing both the tri- and tetra-nitrates of pentaerythritol. The cake was dissolved in acetone and neutralized in solution with ammonium carbonate, after which the PETN was precipitated by the addition of water. After filtration, the PETRIN was recovered from the filtrate by stripping off the solvent under vacuum. Yields by this process averaged about 40%.

An improved process, called the "B process," used the same primary reaction procedure but a different work-up procedure. After the reaction holding period, water was added to dilute the mixed acid and the batch was extracted in situ with methylene chloride. The organic layer was separated, neutralized with aqueous sodium bicarbonate, and stripped of methylene chloride under vacuum to yield the product directly. Yields by this process were about 50% and quality of the product was much improved over that of the "A process."

The "C process," currently in use, involves essentially the simultaneous synthesis and extraction of PETRIN from the reaction mixture. Methylene chloride approximately equal to the total weight of the other components is added to the reaction mixture before the sulfuric acid. After a suitable time following the addition of sulfuric acid, the solvent is removed and replaced by fresh solvent one or more times. The combined extracts are neutralized and concentrated. Because of their initially relatively large volume, PETN must be removed by filtration from the concentrated PETRIN solution before the final solvent is stripped. Yields by this process have been 60% to 65%.

Origin:

The nitration products of pentaerythritol or its derivatives containing not more than three NO₂ groups were patented for use as explosives, propellants or ignition materials in 1936 (German Patents 638,432 and 638,433; CA 31, 1212 (1937)).

A process in which pentaerythritol monoacetate was converted to pentaerythritol trinitrate monoacetate, which was then saponified under carefully controlled conditions to PETRIN, was reported in 1954 (N. S. Marans, D. E. Elrick and R. F. Preckel, J Am Chem Soc 76, 1304). PETRIN was also prepared by the nitration of pentaerythritol with a mixture of 80% HNO₃ and 80% H₂SO₄ in 1955 (A. T. Camp, N. S. Marans, D. E. Elrick and R. F. Preckel, J Am Chem Soc 77, 751).

References:⁵⁴

(a) Rohm and Haas Company, Redstone Arsenal Division, Process for the Manufacture of Pentaerythritol Trinitrate Monoacrylate and Petrin Acrylate Propellants, 12 March 1956.

(b) E. Berlow, R. H. Barth and J. E. Snow, The Pentaerythritols, ACS Monograph No. 136, p. 65, Reinhold Publishing Corporation, New York, 1958.

(c) R. H. Pierson, An Infrared Spectrophotometric Method for Determination of Acetone Content of Pentaerythritoltrinitrate, U.S. Naval Ordnance Test Station Report NOTS 1877, NAVORD Report No. 5649, 3 February 1958.

⁵⁴See footnote 1, page 10.

Pentaerythritol Trinitroacrylate (PETRIN Acrylate)
(Trinitroxypentaerythritol Acrylate)

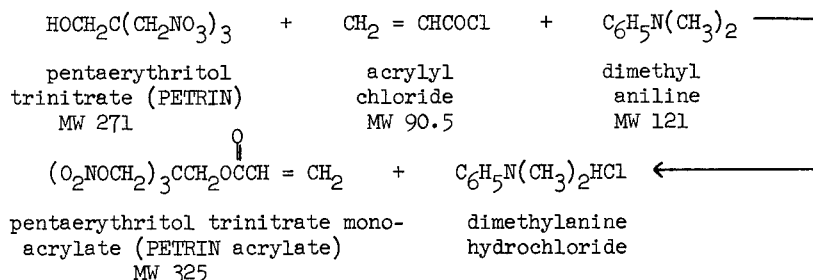
AMCP 706-177

Composition: % C 29.5 H 3.4 N 12.9 O 54.2 C/H Ratio 0.239 $\text{CH}_2 = \text{CH} - \text{CO}_2\text{CH}_2\text{C}(\text{CH}_2\text{ONO}_2)_2$	Molecular Weight: (C ₈ H ₁₁ N ₃ O ₁₁) 325 (Monomer) Oxygen Balance: CO ₂ % -54 CO % -12 Density: gm/cc Melting Point: °C 78 to 79 Freezing Point: °C Boiling Point: °C Refractive Index, n _D ²⁰ n _D ²⁵ n _D ³⁰
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	
Friction Pendulum Test: Steel Shoe Fiber Shoe	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C 200 Gram Bomb Sand Test: Sand, gm
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl Ballistic Mortar, % TNT: Trauzl Test, % TNT:
75°C International Heat Test: % Loss in 48 Hrs	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT
Flammability Index:	
Hygroscopicity: % Nil	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second
Volatility:	

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Color: White
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Principal Uses: Ingredient of composite rocket propellants
	Method of Loading:
	Loading Density: gm/cc
	Storage: Method Dry at temperatures below melting point Hazard Class (Quantity-Distance) Compatibility Group Exudation None
	Heat of: <div style="display: flex; justify-content: space-between;"> Combustion, cal/gm 2923 </div> <div style="display: flex; justify-content: space-between;"> Explosion, cal/gm 791 </div>

Preparation:

(a)



The original synthesis for PETRIN acrylate employed trifluoroacetic anhydride and glacial acrylic acid as the acrylation agent for PETRIN. These two materials were charged to a reaction vessel and the initial reaction was controlled by the slow addition of PETRIN at a temperature of 10° to 15°C. Following a period of one hour, the batch was drowned in water, precipitating the PETRIN acrylate. This solid was separated by filtration, dissolved in chloroform, and neutralized in solution with sodium bicarbonate. The product was then crystallized during a period of 16 hours at 0°C and dried under vacuum to remove traces of solvent. The yield for this process was about 60%.

A significant improvement in yield (to about 74%) and purity (approximately 98%) was realized by the substitution of methanol for chloroform and crystallization of the product from the solution without neutralization, residual acid being removed by washing the filter cake with water.

Because of the high cost and hygroscopic nature of trifluoroacetic anhydride, a new process, based on dimethylaniline and acrylyl chloride, was considered. This process is currently under development in the Rohm and Haas Chemical Processing facilities and is not considered optimum. Yields averaged 46% and product purities averaged 93.5%.

PETRIN Acrylate Propellants:

PETRIN acrylate could be used as a monopropellant because it has a specific impulse of 214 lb-sec/lb and a burning rate of 0.2 in/sec. The addition of an oxidizer increases both the impulse and burning rate.

A composition which presently appears most promising is as follows:

	Composition NM	
PETRIN acrylate (>97% purity), %	34.3	(binder)
Triethylene glycol trinitrate, %	11.8	(plasticizer)
Glycol diacrylate, %	2.9	(crosslinker)
Ammonium perchlorate, %	51.0	(oxidizer)
Hydroquinone, %	0.014	(polymerization inhibitor)

Measured specific impulse 238 lb-sec/lb, at density of 1.3.

Reference:⁵⁵

(a) Rohm and Haas Company, Redstone Arsenal Division, Process for the Manufacture of Pentaerythritol Tetranitrate Monoacrylate and Petrin Acrylate Propellants, 12 March 1956.

⁵⁵See footnote 1, page 10.

Composition:			Molecular Weight:	<u>50/50</u> 265	<u>10/90</u> 234
%			Oxygen Balance:		
PETN	50	10	CO ₂ %	-42	-68
TNT	50	90	CO %	- 5	-21
C/H Ratio			Density: gm/cc	1.65	1.60
			Melting Point: °C		76
			Freezing Point: °C		
Impact Sensitivity, 2 Kg Wt:			Boiling Point: °C		
Bureau of Mines Apparatus, cm	<u>50/50</u> 34	<u>10/90</u> 65	Refractive Index, n ₂₀ ^D n ₂₅ ^D n ₃₀ ^D		
Sample Wt 20 mg					
Picatinny Arsenal Apparatus, in.	12	14			
Sample Wt, mg	15	18			
Friction Pendulum Test:			Vacuum Stability Test:	<u>50/50</u>	<u>10/90</u>
Steel Shoe		Unaffected	cc/40 Hrs, at		
Fiber Shoe		Unaffected	90°C		
Rifle Bullet Impact Test: 25 Trials, 50/50			100°C	3.0	3.0
Explosions	%		120°C	11+	11+
Partials	72		135°C	--	--
Burned	20		150°C	--	--
Unaffected	0				
	8		200 Gram Bomb Sand Test:		
			Sand, gm	55.6	49.5
Explosion Temperature:	°C, 50/50		Sensitivity to Initiation:	<u>50/50</u>	
Seconds, 0.1 (no cap used)	290		Minimum Detonating Charge, gm		
1	266		Mercury Fulminate		0.19*
5 Decomposes	220		Lead Azide		0.13*
10	204		Tetryl		--
15	197		*Alternative initiating charges.		
20	>190		Ballistic Mortar, % TNT:	(a)	126
75°C International Heat Test:			Trauzl Test, % TNT:	(b)	122
% Loss in 48 Hrs			Plate Dent Test:	(c)	
			Method		B
100°C Heat Test:	<u>50/50</u>		Condition		Cast
% Loss, 1st 48 Hrs	0.0		Confined		No
% Loss, 2nd 48 Hrs	0.2		Density, gm/cc		1.66
Explosion in 100 Hrs	None		Brisance, % TNT		121
Flammability Index: Will not continue to burn			Detonation Rate:		
			Confinement		None
			Condition		Cast
Hygroscopicity: %	<u>50/50</u>	<u>10/90</u>	Charge Diameter, in.		1.0
30°C, 90% RH	None	None	Density, gm/cc		1.66
Volatility:			Rate, meters/second		7465

Booster Sensitivity Test: (d) <u>50/50</u> Condition Pressed Cast Tetryl, gm 100 100 Wax, in. for 50% Detonation 2.36 2.08 Wax, gm Density, gm/cc 1.60 1.65	Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH , kcal/mol) Temperature Range, °C Phase
Heat of: Combustion, cal/gm Explosion, cal/gm 1220 Gas Volume, cc/gm Formation, cal/gm Fusion, cal/gm	Armor Plate Impact Test: <u>50/50</u> 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec 170 Aluminum Fineness 500-lb General Purpose Bombs: Plate Thickness, inches 1 1¼ 1½ 1¾
Specific Heat: cal/gm/°C	Bomb Drop Test: T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete: Max Safe Drop, ft 500-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order 1000-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order
Burning Rate: cm/sec	
Thermal Conductivity: cal/sec/cm/°C	
Coefficient of Expansion: Linear, %/°C Volume, %/°C	
Hardness, Mohs' Scale:	
Young's Modulus: E', dynes/cm ² E, lb/inch ² Density, gm/cc	
Compressive Strength: lb/inch ² 2000-2200 Density, gm/cc 1.68	
Vapor Pressure: °C mm Mercury	

Fragmentation Test: <u>50/50</u> 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc 1.65 Charge Wt, lb 2.147 Total No. of Fragments: For TNT 703 For Subject HE 968 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc 1.65 Charge Wt, lb 0.872 Total No. of Fragments: For TNT 514 For Subject HE 650 Fragment Velocity: ft/sec At 9 ft 2810 At 25½ ft 2580 Density, gm/cc 1.66	Shaped Charge Effectiveness, TNT = 100: <u>50/50</u> <u>10/90</u> <u>50/50</u> <u>25/75</u> Glass Cones (f) Steel Cones (g) Hole Volume 157 105 149 119 Hole Depth 116 116 131 119 Color: Yellow-white Principal Uses: Shaped charges, bursting charges, demolition blocks Method of Loading: Cast Loading Density: gm/cc <u>50/50</u> <u>10/90</u> 1.65 1.60
Blast (Relative to TNT): (e) Air: Peak Pressure 105 Impulse 107 Energy -- Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy <u>Eutectic Temperature, °C:</u> 76 gm PETN/100 gm TNT 76°C 13.0 95°C 28.3	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation Compatibility with Metals: <u>Dry:</u> Copper, brass, aluminum, magnesium, magnesium-aluminum alloy, mild steel coated with acid-proof black paint, and mild steel plated with copper, cadmium or nickel are not affected. Zinc plated steel is only slightly affected. <u>Wet:</u> Stainless steel, aluminum and mild steel coated with acid-proof black paint are not affected. Copper, brass, magnesium, magnesium-aluminum alloy, mild steel and mild steel plated with copper, cadmium, zinc or nickel are slightly affected. <u>Effect of Temperature on</u> (h) <u>Rate of Detonation:</u> <u>50/50</u> 16 hrs at, °C -54 21 Density, gm/cc 1.67 1.66 Rate, m/sec 7470 7440

Preparation:

Pentolite is manufactured by either the slurry method or coprecipitation of PETN and TNT. In the slurry method PETN, in water, is stirred and heated above 80°C. TNT is added and when molten, it coats the particles of PETN. The slurry is cooled with rapid stirring and the separated granules are collected on a filter and dried below 75°C.

In coprecipitation, PETN and TNT are dissolved separately in acetone. The solutions are mixed and the explosives are precipitated simultaneously by pouring the mixed solution into cold water under vigorous agitation. The precipitated solid is collected on a filter and dried in air.

Origin:

Standardized during World War II, with the 50-50 PETN/TNT mixture being the more important for bursting charges and booster-surround charges.

References:⁵⁶

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.
- (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (d) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.
- (e) W. R. Tomlinson, Jr., Blast Effects of Bomb Explosives, PA Tech Div Lecture, 9 April 1948.
- (f) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Sec III, Variation of Cavity Effect with Explosive Composition, NDRC Contract W672-ORD-5723.
- (g) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Final Report, Contract W-672-ORD-5723, E. Lab, du Pont, 18 September 1943.
- (h) W. F. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Different Temperatures, PATR No. 2383, November 1956.
- (i) Also see the following Picatinny Arsenal Technical Report on Pentolite:

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>
1360	1291	1212	1133	1284	1325	1436	1477	1388
1420	1451	1262	1193	2004		1466	1677	1598
1570	1651	1372	1213			1796	1737	1668
			1363					1838

⁵⁶See footnote 1, page 10.

Composition:		Molecular Weight: ($C_5H_8N_4O_{12}$)		316
%		Oxygen Balance:		
C	19.0	CO ₂ %		-10
H	2.5	CO %		15
N	17.7	Density: gm/cc	Crystal	1.77
O	60.8	Melting Point: °C		141
C/H Ratio	0.134	Freezing Point: °C		
Impact Sensitivity, 2 Kg Wt:		Boiling Point: °C		
Bureau of Mines Apparatus, cm	17	Refractive Index, n_{20}^D		
Sample Wt 20 mg		n_{25}^D		
Picatinny Arsenal Apparatus, in.	6	n_{30}^D		
Sample Wt, mg	16	Vacuum Stability Test:		
Friction Pendulum Test:		cc/40 Hrs, at		
Steel Shoe	Crackles	90°C		
Fiber Shoe	Unaffected	100°C		0.5
Rifle Bullet Impact Test: 5 Trials *		120°C		11+
	%	135°C		
Explosions	100	150°C		
Partial	0	200 Gram Bomb Sand Test:		
Burned	0	Sand, gm		62.7
Unaffected	0	Sensitivity to Initiation:		
*4.86% moisture in samples		Minimum Detonating Charge, gm		
Explosion Temperature: °C		Mercury Fulminate		0.17*
Seconds, 0.1 (no cap used)	272	Lead Azide		0.03*
1	244	Tetryl		--
5 Decomposes	225	*Alternative initiating charges.		
10	211	Ballistic Mortar, % TNT:	(a)	145
15	--	Trauzl Test, % TNT:	(b)	173
20	--	Plate Dent Test:	(c)	
75°C International Heat Test:		Method		A
% Loss in 48 Hrs	0.02	Condition		Pressed
100°C Heat Test:		Confined		Yes
% Loss, 1st 48 Hrs	0.1	Density, gm/cc		1.50
% Loss, 2nd 48 Hrs	0.0	Brisance, % TNT		129
Explosion in 100 Hrs	None	Detonation Rate:		
Flammability Index: Will not continue to burn		Confinement		None
Hygroscopicity: % 30°C, 90% RH		Condition		Pressed
Volatility:		Charge Diameter, in.		1.00
	0.0	Density, gm/cc		1.70
		Rate, meters/second		8300

Booster Sensitivity Test: Condition (c) Pressed Tetryl, gm 5 Wax, in. for 50% Detonation Wax, gm 3 Density, gm/cc 1.6	Decomposition Equation: (e) (e) (f) Oxygen, atoms/sec $10^{19.8}$ $10^{20.6}$ $10^{23.1}$ (Z/sec) Heat, kilocalorie/mole 47.0 50.9 52.3 (ΔH , kcal/mol) Temperature Range, °C 161-233 108-120 137-157 Phase Liquid Solid At melt- ing point
Heat of: Combustion, cal/gm 1960 Explosion, cal/gm 1385 Gas Volume, cc/gm 790 Formation, cal/gm 383 Fusion, cal/gm	Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bombs: Plate Thickness, inches 1 1¼ 1½ 1¾
Specific Heat: cal/gm/°C (d) Room Temperature 0.26	
Burning Rate: cm/sec	
Thermal Conductivity: cal/sec/cm/°C	
Coefficient of Expansion: Linear, %/°C Volume, %/°C	Bomb Drop Test: T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete: Max Safe Drop, ft 500-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order 1000-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order
Hardness, Mohs' Scale: 1.9	
Young's Modulus: E', dynes/cm² E, lb/inch² Density, gm/cc	
Compressive Strength: lb/inch²	
Vapor Pressure: °C mm Mercury	

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones Hole Volume Hole Depth
	Color: White
	Principal Uses: Class A - Detonating fuse and boosters Class B - Priming compositions
	Method of Loading:
	Loading Density: gm/cc psi x 10 ³ 3 5 10 20 30 40 1.37 1.58 1.64 1.71 1.73 1.74
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Wet Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group M (wet) Exudation None
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Bulk Modulus at Room Temperature (25°-30°C): (i) Dynes/cm ² x 10 ⁻¹⁰ 4.60 Density, gm/cc 1.77

Compatibility with Metals:

Dry: Copper, brass, aluminum, magnesium, magnesium-aluminum alloy, stainless steel, mild steel, mild steel coated with acid-proof black paint and mild steel plated with copper, cadmium, nickel or zinc are not affected.

Wet: Stainless steel is unaffected and aluminum only vary slightly so after prolonged storage. Copper, brass, magnesium, magnesium-aluminum alloy, mild steel, mild steel coated with acid-proof black paint and mild steel plated with cadmium, copper, nickel or zinc are affected.

Sensitivity of PETN to electrostatic discharge, joules; Through 100 Mesh: (g)

Unconfined	0.06
Confined	0.21

Solubility, grams of PETN per 100 grams (%) of: (h)

<u>Trichlorethylene or Alcohol</u>		<u>Acetone</u>		<u>Benzene</u>		<u>Toluene</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
0	0.070	0	14.37	0	0.150	0	0.150
20	0.195	20	24.95	20	0.450	20	0.430
40	0.415	40	30.56	40	1.160	40	0.620
60	1.205	60	42.68	80	7.900	60	2.490
						80	5.850
						100	15.920
						112	30.900

<u>Methyl acetate</u>		<u>Ether</u>		<u>β-Ethoxy-ethyl- acetate</u>		<u>Chlorobenzene</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
20	13	0	0.200	20	1.5	20	0.35
30	17	20	0.340	30	4.1	30	2.8
40	22	34.7	0.450	40	7.6	40	6.1
50	31			50	11.2	50	9.2
				60	14.2	60	12.2

<u>Ethylenedichloride</u>		<u>Methanol</u>		<u>Tetrachloroethane</u>		<u>Carbon tetrachloride</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
10	0.9	20	0.46	20	0.18	20	0.096
30	1.5	40	1.15	30	0.27	30	0.108
50	2.6	60	2.6	40	0.40	40	0.118
				50	0.58	50	0.121

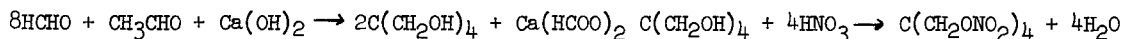
PETN (Pentaerythritol Tetranitrate)

<u>Isopropanol</u>		<u>Isobutanol</u>		<u>Chloroform</u>		<u>TNT</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
15	0.02	20	0.27	20	0.09	80	19.3
20	0.04	30	0.31			85	25.0
30	0.15	40	0.39			90	32.1
40	0.36	50	0.52			95	39.5
50	0.46					100	48.6
						105	58.2
						110	70.0
						115	87.8
						120	115
						125	161

Eutetic of the system PETN-TNT is about 13% PETN and 87% TNT at 76°C.

Preparation:

(Nitroglycerin and Nitroglycerin Explosives, Naoum)



1. In this preparation 1940 gm of formaldehyde and 600 gm of acetaldehyde are dissolved in 90 liters of water containing 1600 gm suspended slaked lime. The reaction is complete in about 3 weeks if agitated several times a day. The solution is filtered, the calcium formate precipitated with oxalic acid, filtered off, and the water removed under reduced pressure. On cooling the mother liquor about 1200 gm crude pentaerythritol, melting point 235°-240°C are obtained. Purification is readily effected by stirring with a little alcohol, filtering and recrystallization from water.

2. To 400 cc of strong white nitric acid, are added 100 gm of pentaerythritol (through 50 mesh), at 5°C or below, under good agitation. After addition is complete stirring, at 5°C, is continued for 15 minutes. The mixture is drowned in 3 liters of ice-water, filtered, the product washed free of acid with water and then digested 1 hour in 1 liter of hot 0.5% sodium carbonate solution. The product is filtered, and recrystallized from acetone.

Origin:

PETN was known as an explosive in 1894 when it was proposed as an addition to smokeless powders to raise their flammability and ease of combustion (German Patent 81,664 (1894)). Modern methods of preparation are described by Vignon and Gerin (Compt rend 133, 590 (1901) and German Patent 265,025 (1912) and A. Stettbacher (Z ges Schiess - Sprengstoffw 11, 112, 182 (1916) and 24, 259 (1929)). PETN was not used on a practical basis until after World War I.

Destruction by Chemical Decomposition:

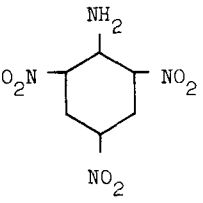
PETN is decomposed by dissolving in 8 times its weight of technical grade acetone and burning the solution in a shallow container. If preferred, warm the acetone solution to 40°C, stir and add 7 parts by weight, to each part of PETN, of a solution of 1 part sodium sulfide ($\text{Na}_2\text{S} \cdot 9\text{H}_2\text{O}$) in 2 parts water heated to 80°C. The aqueous solution should be added at such a rate that the acetone solution does not boil. After mixing is complete continue stirring for one-half hour.

References:⁵⁷

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) Ph. Naoum, Z ges Schiess - Sprengstoffw, pp. 181, 229, 267 (27 June 1932).
- (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (d) International Critical Tables.
- (e) M. A. Cook and M. T. Abegg, "Isothermal Decomposition of Explosives," University of Utah, Ind & Eng Chem, (June 1956), pp. 1090-1095.
- (f) A. J. B. Robertson, "The Thermal Decomposition of Pentaerythritol Tetranitrate, Nitroglycerin, Ethylenediamine Dinitrate and Ammonium Nitrate," J Chem Ind 67, 221 (1948).
- (g) F. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U.S. Dept of Int, Bureau of Mines, RI 3852, 1946.
- (h) Various sources in the open literature.
- (i) W. S. Cramer, Bulk Compressibility Data on Several High Explosives, NAVORD Report No. 4380, 15 September 1956.
- (j) Also see the following Picatinny Arsenal Technical Reports on PETN:

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
760	1041	772	843	904	1305	1246	407	318	1379
1170	1311	922	863	1274	1325	1276	527	838	1429
1260	1381	1182	1063	1284	1445	1316	857	1238	1489
1290	1451	1192	1133	1414	1705	1376	1247	1318	1559
1300	1561	1212	1253		1885	1446	1517	1388	2179
1320	1611	1262	1343		2125	1456	1617	1568	
1360	1651	1342	1493			1466	1737	1598	
1380		1352	1533			1556	1797	1838	
1390		1372				1796		2178	
1430		1452							
1450									
1570									

⁵⁷See footnote 1, page 10.

Composition: % C 31.5 H 1.8 N 24.5 O 42.2 C/H Ratio 0.500		Molecular Weight: ($C_6H_4N_4O_6$) 228
		Oxygen Balance: CO ₂ % -56 CO % -14
		Density: gm/cc Crystal 1.76
		Melting Point: °C 189 to 190
		Freezing Point: °C
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 23 Sample Wt, mg 20		Boiling Point: °C Decomposes before boiling point
		Refractive Index, n_{20}^D n_{25}^D n_{30}^D
Friction Pendulum Test: Steel Shoe Fiber Shoe		Vacuum Stability Test: cc/40 Hrs, at 90°C ---- 100°C 0.9 120°C 135°C 150°C
Rifle Bullet Impact Test: Trials % Explosions Partial Burned Unaffected		200 Gram Bomb Sand Test: Sand, gm 48.1
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 10 15 20		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate ---- Lead Azide 0.30 Tetryl ----
75°C International Heat Test: % Loss in 48 Hrs 100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs		Ballistic Mortar, % TNT: 100
		Trauzl Test, % TNT: 107
Flammability Index: Hygroscopicity: % Volatility:		Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT
		Detonation Rate: Confinement None Condition Pressed Charge Diameter, in. 0.5 Density, gm/cc 1.72 Rate, meters/second 7300

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones Hole Volume Hole Depth
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Color: Yellow
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Principal Uses: High temperature heat resistant explosive
	Method of Loading: Pressed
	Loading Density: gm/cc At 50,000 psi 1.72
	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation None
	Solubility: Insoluble in water, slightly soluble in alcohol and ether. Soluble in hot glacial acetic acid, hot ethyl acetate and in benzene and acetone. Heat of: Combustion, cal/gm (a) 2962 Explosion, cal/gm 564 Formation, cal/gm (a) 131

Preparation:

Five grams of picryl chloride were dissolved in 180 milliliters of absolute methanol. The solution was then saturated with anhydrous, gaseous ammonia. The time required was approximately 30 minutes. The amino derivative precipitated in 78% yield (3.6 gm) melting at 190°C (literature MP 189°C).

Origin:

Picramide (2,4,6-trinitroaniline) was first prepared in 1854 by Pisani who treated picryl chloride with ammonium carbonate (CR 39, 853). The use of picramide, as a brisant explosive, was patented by Chemische Fabrik Griesheim 26 May 1894 (German Patent 84,628). Meisenheimer and Patzig reacted trinitrobenzene with hydroxylamine in cold alcohol solution to obtain picramide (Ber 39, 2534 (1906)). Witt and Witte obtained the compound by nitrating a solution of aniline in glacial acetic acid or concentrated H₂SO₄ at about 5°C with concentrated HNO₃ (Ber 41, 3091 (1908)). Holleman gives details of the preparation from p-nitroaniline and from acetanilide (Rec trav chim 49, 112 (1930)).

Reference:⁵⁸

(a) William H. Rinkenbach, "The Heats of Combustion and Formation of Aromatic Nitro Compounds," J Am Chem Soc 52, 116 (1930).

⁵⁸See footnote 1, page 10.

Composition: % Explosive D 52 TNT 48 C/H Ratio	Molecular Weight: 236	
	Oxygen Balance: CO ₂ % -63 CO % -19	
	Density: gm/cc	Cast 1.62
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 100+ Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 17 Sample Wt, mg 19	Boiling Point: °C	
	Refractive Index, n_D^{20} n_D^{25} n_D^{30}	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.37 120°C 0.68 135°C -- 150°C 0.7	
Rifle Bullet Impact Test: Trials Explosions % 0 Partial 0 Burned 40 Unaffected 60	200 Gram Bomb Sand Test: Sand, gm 45.0	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 456 1 354 5 Decomposes 285 10 265 15 260 20 255	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.05	
75°C International Heat Test: % Loss in 48 Hrs 0.0	Ballistic Mortar, % TNT: (a) 100	
	Trauzl Test, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs 0.0 % Loss, 2nd 48 Hrs 0.05 Explosion in 100 Hrs None	Plate Dent Test: (b) Method B Condition Cast Confined No Density, gm/cc 1.63 Brisance, % TNT 100	
Flammability Index:	Detonation Rate: (b) Confinement None Condition Cast Charge Diameter, in. 1.0 Density, gm/cc 1.63 Rate, meters/second 6970	
Hygroscopicity: % 30°C, 90% RH 0.02		
Volatility:		

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc 1.61 Charge Wt, lb 2.075 Total No. of Fragments: For TNT 703 For Subject HE 769 3 inch HE, M42A1 Projectile, Lot KC-3: Density, gm/cc 1.61 Charge Wt, lb 0.850 Total No. of Fragments: For TNT 514 For Subject HE 487 Fragment Velocity: ft/sec At 9 ft 2590 At 25½ ft 2320 Density, gm/cc 1.62	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones Hole Volume Hole Depth Color: Brown-yellow Principal Uses: AP, SAP projectiles and bombs Method of Loading: Cast Loading Density: gm/cc 1.62 Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation None at 65°C
Blast (Relative to TNT): Air: Peak Pressure 100 Impulse 100 Energy -- Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy <u>Bomb Drop Test:</u> T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete: Max Safe Drop, ft 10,000-12,000	<u>Preparation:</u> Picratol is made by heating TNT to about 90°C in a steam-jacketed melt kettle. Explosive D is added slowly, without preheating, and the mixture stirred until uniform in composition. This slurry is cooled to about 85°C and poured into the appropriate ammunition component. <u>Origin:</u> Developed during World War II as an insensitive, melt-loaded AP bomb and projectile filler. <u>Booster Sensitivity Test:</u> (c) Condition Cast Tetryl, gm 100 Wax, in. for 50% Detonation 1.00 Density, gm/cc 1.63

References:⁵⁹

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

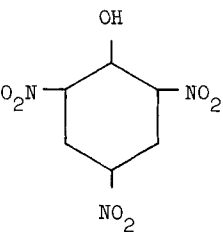
(c) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Teteryl in Boosters, NOL Memo 10,303, 15 June 1949.

(d) R. W. Drake, Fragment Velocity and Panel Penetration of Several Explosives in Simulated Shells, OSRD Report No. 5622, 2 January 1946.

(e) Also see the following Picatinny Arsenal Technical Reports on Picratol:

<u>0</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
1470	1885	1466	1737	1838	1729
		1796	1797		
		1956			

⁵⁹See footnote 1, page 10.

Composition: % C 31.5 H 1.3 N 18.3 O 48.9 C/H Ratio 0.656				Molecular Weight: (C ₆ H ₃ N ₃ O ₇) 229	
				Oxygen Balance: CO ₂ % -45 CO % -3.5	
				Density: gm/cc Crystal 1.76	
				Melting Point: °C 122	
				Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 85 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 13 Sample Wt, mg 17				Boiling Point: °C	
				Refractive Index, n ₂₀ ^D n ₂₅ ^D n ₃₀ ^D	
Friction Pendulum Test: Steel Shoe Fiber Shoe				Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.2 120°C 0.5 135°C 150°C	
Rifle Bullet Impact Test: Trials Explosions 0 Partial 60 Burned 40 Unaffected 0				200 Gram Bomb Sand Test: Sand, gm 48.5	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 320 10 15 20				Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.26* Lead Azide 0.24* Tetryl *Alternative initiating charges.	
				Ballistic Mortar, % TNT: (a) 112	
				Trauzl Test, % TNT: (b) 101	
75°C International Heat Test: % Loss in 48 Hrs 0.05				Plate Dent Test: (c) Method A Condition Pressed Confined No Density, gm/cc 1.50 Brisance, % TNT 107	
100°C Heat Test: % Loss, 1st 48 Hrs 0.03 % Loss, 2nd 48 Hrs 0.09 Explosion in 100 Hrs None				Detonation Rate: (d) Confinement Unconfined Condition Pressed Cast Charge Diameter, in. 1.0 1.25 Density, gm/cc 1.64 1.71 Rate, meters/second 5270 7350	
Flammability Index:					
Hygroscopicity: % 30°C, 90% RH 0.04					
Volatility:					

Booster Sensitivity Test: Condition Pressed Cast Tetryl, gm 10 5 Wax, in. for 50 % Detonation Wax, gm 2 0 Density, gm/cc 1.6 1.7		Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH , kcal/mol) Temperature Range, °C Phase	
Heat of: Combustion, cal/gm 2672 Explosion, cal/gm 1000 Gas Volume, cc/gm 675 Formation, cal/gm 248 Fusion, cal/gm 20.4 Temperature, °C 122		Armor Plate Impact Test: 60 mm Mortar Projectile: 50 % Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bombs: Plate Thickness, inches 1 1¼ 1½ 1¾	
Specific Heat: cal/gm/°C (e) °C 0 0.235 30 0.258 60 0.282 90 0.310 120 0.337			
Burning Rate: cm/sec			
Thermal Conductivity: (f) cal/sec/cm/°C 6.24 x 10 ⁻⁴ Density, gm/cc 1.406			
Coefficient of Expansion: Linear, %/°C Volume, %/°C			
Hardness, Mohs' Scale: 2.1			
Young's Modulus: E', dynes/cm² E, lb/inch² Density, gm/cc			
Compressive Strength: lb/inch²			
Vapor Pressure: °C mm Mercury 195 2 255 50		Bomb Drop Test: T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete: Max Safe Drop, ft 500-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order 1000-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order	

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-3: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth																		
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Color: Yellow Principal Uses: Formerly projectile filler, now explosive admixture; and for the manufacture of Explosive D																		
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Method of Loading: Pressed <table border="1"> <tr> <th colspan="2">Loading Density: gm/cc</th> <th colspan="4">psi x 10³</th> </tr> <tr> <td>3</td> <td>5</td> <td>10</td> <td>12</td> <td>15</td> <td>20</td> </tr> <tr> <td>1.40</td> <td>1.50</td> <td>1.57</td> <td>1.59</td> <td>1.61</td> <td>1.64</td> </tr> </table> Storage: <div style="display: flex; justify-content: space-between;"> Method Dry </div> <div style="display: flex; justify-content: space-between;"> Hazard Class (Quantity-Distance) Class 9 </div> <div style="display: flex; justify-content: space-between;"> Compatibility Group Group I </div> <div style="display: flex; justify-content: space-between;"> Exudation None </div>	Loading Density: gm/cc		psi x 10 ³				3	5	10	12	15	20	1.40	1.50	1.57	1.59	1.61	1.64
Loading Density: gm/cc		psi x 10 ³																	
3	5	10	12	15	20														
1.40	1.50	1.57	1.59	1.61	1.64														

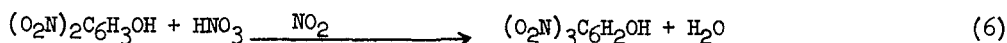
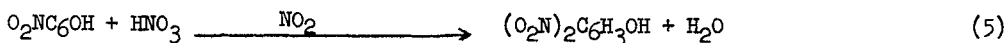
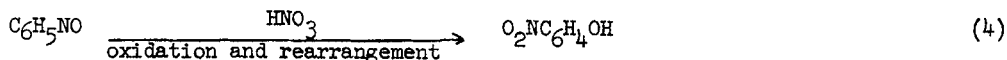
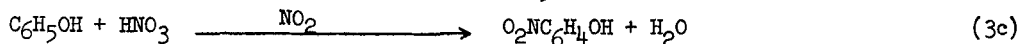
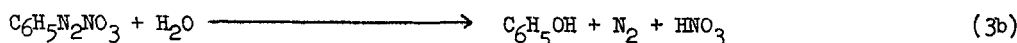
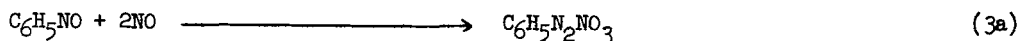
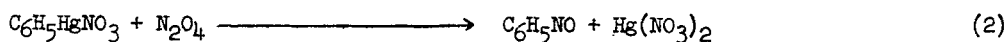
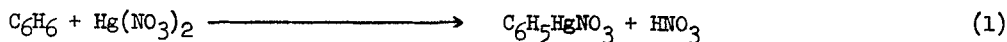
Solubility: grams per 100 grams (%) of: (g)

<u>Water</u>		<u>Alcohol</u>		<u>Benzene</u>		<u>Toluene</u>		<u>Ether</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
0	0.85	0	4.5	0	~ 2	20	~ 13	20	~ 3
20	1.17	20	6.9	20	9.6	60	~ 30	34.7	3.96
40	1.88	40	12.0	40	27.5				
60	2.98			60	59				
80	4.53								
100	7.1								

<u>Chloroform</u>		<u>Ethyl acetate</u>		<u>Carbon tetrachloride</u>		<u>Pyridine</u>		<u>Acetone</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
20	~ 2	20	42	20	~ 0.07	10	24	20	125
60	~ 6	30	50	60	~ 0.4	30	37.5	30	137
		40	58			50	58	40	164
		50	69					50	208

<u>Methanol</u>		<u>Isopropyl alcohol</u>		<u>Propanol-1</u>		<u>Carbon disulfide</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
0	14	10	6.4	0	2.4	20	0.12
20	19	30	9.8	20	3.3	30	0.16
40	31	50	15.5	40	5.4		
50	41			50	7.4		

Preparation: (Summary Report of NDRC, Div 8, Vol I)



The two variables of greatest importance in this process are nitric acid concentration and the effective concentration of benzene (i.e., benzene dissolved in the oxynitration solution). The optimal concentration of nitric acid is in the range 10.4 to 11.6 molar (or the equivalent of 50% to 55% by weight for pure acid). The acid concentration greatly influences the overall rate of reaction, below 10.4 molar the rate falls off rapidly, while above 10.4 molar the rates of both the oxynitration reaction and various side reactions, such as direct nitration, increase rapidly. The range mentioned above seems, in general, to give the lowest proportion of neutral nitro-compounds to nitro-phenols with, at the same time, an adequate rate of oxynitration. The oxynitration solution must be fortified frequently, or, preferably, continuously with nitric acid. Strengths of nitric acid between 95% and 98% are best, due to the smaller increase in reaction volume than if weaker acid were used. The use of absolute nitric acid requires that its direct contact with liquid benzene be avoided.

The effective concentration of benzene is probably the most critical variable affecting the proportion of neutral nitro-compounds to nitrophenols and amounts of colored by-products. Saturation of the oxynitration solution with benzene is undesirable and thus in batch processes slow benzene addition is preferable to the addition of it in one portion; in continuous processes where an excess of benzene is used the rate of agitation is important.

The concentration of mercuric nitrate catalyst does not appear to be a critical factor over a fairly wide range. Concentrations of 0.37 to 0.5 mole of mercuric nitrate per liter of oxynitration solution have been found to give satisfactory results in most cases.

A continuous process, known as the continuous solution process, works on the following cycle. The oxynitration solution is saturated with benzene by vigorous agitation with excess benzene at room temperature, the saturated solution is separated from excess benzene and circulated through a heated coil; it is then cooled to room temperature and agitated again, with benzene, which extracts the organic product and resaturates the oxynitration solution. In evaluating this process, the rate of formation of dinitrophenol per liter of reacting solution in the coil is determined; 70 gm of dinitrophenol per liter per hour is representative performance. The dinitrophenol is, of course, nitrated to picric acid.

Origin:

Picric Acid was first prepared in 1771 by Woulff who found the reaction of nitric acid and indigo yielded a dye. Hausmann isolated Picric Acid in 1778 and studied it further (Journal de physique 32, 165 (1788)). The preparation was studied by many chemists but in 1841 Laurent established its identity (Ann chim phys III, 3, 221 (1841)). It was used as a yellow dye until Turpin, in 1885, proposed Picric Acid as a bursting charge for high explosive shell (French Patent 167,512). The British adopted Picric Acid as a military explosive in 1888 under the name of lyddite and other nations soon began to use it as the first melt-loaded high explosive. Mixtures of other explosives and Picric Acid were developed until it was gradually replaced by TNT about 1900. Today Picric Acid is used for the manufacture of Explosive D.

Destruction by Chemical Decomposition:

Picric Acid is decomposed by dissolving in 25 times its weight of a solution made from 1 part sodium hydroxide and 21 parts sodium sulfide ($\text{Na}_2\text{S} \cdot 9\text{H}_2\text{O}$) in 200 parts of water. Some hydrogen sulfide and ammonia are evolved.

References:⁶⁰

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) Ph. Naoum, Z ges Schiess-Sprengstoffw, pp. 181, 229, 267 (27 June 1932).

(c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(d) G. H. Messerly, The Rate of Detonation of Various Explosive Compounds, OSRD Report No. 1219, 22 February 1943.

M. D. Hurwitz, The Rate of Detonation of Various Compounds and Mixtures, OSRD Report No. 5611, 15 January 1946.

(e) International Critical Tables.

(f) E. Hutchinson, The Thermal Sensitiveness of Explosives. The Thermal Conductivity Explosive Materials, AC Report No. 2861, First Report, August 1942.

(g) Values taken from various sources in the open literature.

(h) Also see the following Picatinny Arsenal Technical Reports on Picric Acid:

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
1651	132	1383	694	65	266	1347	1118	1549
	582		764	425	556	1557		
	1172		874	1585	926			
	1352				976			
	1372				986			
					1446			
					1556			

⁶⁰See footnote 1, page 10.

Composition: % PETN 81 Gulf Crown E Oil 19 C/H Ratio	Molecular Weight: 310	
	Oxygen Balance: CO ₂ % -74 CO % -31	
	Density: gm/cc	Hand tamped 1.35
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 11 Sample Wt, mg 27	Boiling Point: °C	
	Refractive Index, n ₂₀ ^D n ₂₅ ^D n ₃₀ ^D	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.48 120°C 16 hours 11+ 135°C 150°C	
Rifle Bullet Impact Test: Trials % Explosions 0 Partials 0 Burned 0 Unaffected 100	200 Gram Bomb Sand Test: Sand, gm 41.6	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes* 10 15 20 *No value obtained.	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.20* Lead Azide 0.20* Tetryl *Alternative initiating charges.	
75°C International Heat Test: % Loss in 48 Hrs	Ballistic Mortar, % TNT:	
	Trauzl Test, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs 0.17 % Loss, 2nd 48 Hrs 0.00 Explosion in 100 Hrs None	Plate Dent Test: (a) Method B Condition Hand tamped Confined No Density, gm/cc 1.33 Brisance, % TNT 76	
Flammability Index:	Detonation Rate: Confinement None Condition Hand tamped Charge Diameter, in. 1.0 Density, gm/cc 1.37 Rate, meters/second 7075	
Hygroscopicity: % 30°C, 90% RH 0.02		
Volatility:		

<p>Fragmentation Test:</p> <p>90 mm HE, M71 Projectile, Lot WC-91:</p> <p>Density, gm/cc 1.33</p> <p>Charge Wt, lb 1.723</p> <p>Total No. of Fragments:</p> <p>For TNT 703</p> <p>For Subject HE 519</p> <p>3 inch HE, M42A1 Projectile, Lot KC-5:</p> <p>Density, gm/cc 1.39</p> <p>Charge Wt, lb 0.735</p> <p>Total No. of Fragments:</p> <p>For TNT 514</p> <p>For Subject HE 428</p> <p>Fragment Velocity: ft/sec</p> <p>At 9 ft</p> <p>At 25½ ft</p> <p>Density, gm/cc</p>	<p>Shaped Charge Effectiveness, TNT = 100:</p> <table> <tr> <td>Glass Cones</td><td>Steel Cones</td></tr> <tr> <td>Hole Volume</td><td></td></tr> <tr> <td>Hole Depth</td><td></td></tr> </table> <p>Color:</p> <p>Principal Uses: Plastic demolition explosive</p> <p>Method of Loading: Hand tamped</p> <p>Loading Density: gm/cc 1.35</p>	Glass Cones	Steel Cones	Hole Volume		Hole Depth			
Glass Cones	Steel Cones								
Hole Volume									
Hole Depth									
<p>Blast (Relative to TNT):</p> <p>Air:</p> <p>Peak Pressure</p> <p>Impulse</p> <p>Energy</p> <p>Air, Confined:</p> <p>Impulse</p> <p>Under Water:</p> <p>Peak Pressure</p> <p>Impulse</p> <p>Energy</p> <p>Underground:</p> <p>Peak Pressure</p> <p>Impulse</p> <p>Energy</p> <p><u>Preparation:</u></p> <p>PIPE is manufactured by simple mechanical mixing of PETN in oil.</p>	<p>Storage:</p> <table> <tr> <td>Method</td><td>Dry</td></tr> <tr> <td>Hazard Class (Quantity-Distance)</td><td>Class 9</td></tr> <tr> <td>Compatibility Group</td><td>Group I</td></tr> <tr> <td>Exudation</td><td></td></tr> </table> <p><u>Origin:</u></p> <p>PIPE, a mechanical mixture of PETN and Gulf Crown E Oil, was developed in the United States during World War II.</p> <p><u>References:</u>⁶¹</p> <p>(a) L. C. Smith and E. G. Eyster, <u>Physical Testing of Explosives, Part III-Miscellaneous Sensitivity Tests; Performance Tests</u>, OSRD Report No. 5746, 27 December 1945.</p> <p>(b) S. Livingston, <u>Properties of Explosives PIPE, PIPE and PEP-3</u>, Picatinny Arsenal Technical Report 1517, 24 April 1945.</p>	Method	Dry	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group	Group I	Exudation	
Method	Dry								
Hazard Class (Quantity-Distance)	Class 9								
Compatibility Group	Group I								
Exudation									

⁶¹See footnote 1, page 10.

Composition: % Lead Nitrate 70 TNT 30 C/H Ratio	Molecular Weight: 291	
	Oxygen Balance: CO ₂ % -5.4 CO % +9.3	
	Density: gm/cc	
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm -- Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 13 Sample Wt, mg 22	Boiling Point: °C	
	Refractive Index, n_{20}^D n_{25}^D n_{30}^D	
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm 32.4	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 238 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate -- Lead Azide 0.20 Tetryl 0.10	
	Ballistic Mortar, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs	Trouzi Test, % TNT:	
	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Detonation Rate: (b) Confinement Condition Charge Diameter, in. Density, gm/cc 2.89 Rate, meters/second 4850	
Flammability Index:		
Hygroscopicity: %		
Volatility:		

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones (a) Hole Volume 114 Hole Depth 103 Color: Light yellow Principal Uses: Method of Loading: Cast Loading Density: gm/cc Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation <u>Origin:</u> An explosive containing 70% lead nitrate and 30% TNT has been used in Belgium under the name of "Marcarite." <u>References:</u> ⁶² (a) Eastern Laboratory, du Pont, <u>Investigation of Cavity Effect, Sec III, Variation of Cavity Effect with Explosive Composition</u> , NDRC Contract W-672-ORD-5723. (b) <u>Thorpe's Dictionary of Applied Chemistry</u> , Fourth Edition, Vol IV, Longmans, Green and Company, London - New York - Toronto, p. 464.
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy <u>Preparation:</u> Plumbatol is manufactured by simple mechanical mixing of lead nitrate in molten TNT.	

⁶²See footnote 1, page 10.

Composition: % Nitromethane 100 95 Ethylenediamine -- 5 *The mixture 95/5 Nitromethane/Ethylenediamine is designated PLX (for Picatinny Liquid Explosive). See note under <u>Storage</u> . C/H Ratio			Molecular Weight: $\frac{100}{61}$ $\frac{95/5}{61}$ Oxygen Balance: CO ₂ % -39 -48 CO % -13 -21 Density: gm/cc 1.14 1.12 Melting Point: °C -29 Freezing Point: °C Boiling Point: °C 101 Refractive Index, n _D ²⁰ n _D ²⁵ n _D ³⁰		
Impact Sensitivity, 2 Kg Wt: $\frac{100}{100+}$ $\frac{95/5}{100+}$ Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg 20 20			Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C		
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected			200 Gram Bomb Sand Test: $\frac{100}{8.1}$ $\frac{95/5}{50.6}$ Sand, gm		
Rifle Bullet Impact Test: 10 Trials 5 Trials Explosions % 0 0 Partials 0 0 Burned 0 0 Unaffected 100 100			Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl		
Explosion Temperature: °C °C Seconds, 0.1 $\frac{100}{430}$ $\frac{95/5}{430}$ 1 5 10 15 20			Ballistic Mortar, % TNT: 134 Trauzl Test, % PA 127		
75°C International Heat Test: % Loss in 48 Hrs			Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT		
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs			Detonation Rate: 1/32"* 1/32"* Confinement Glass Glass Condition Liquid Liquid Charge Diameter, in. 1.25 0.94 Density, gm/cc 1.14 1.12 Rate, meters/second 6210 6165 *Tube wall thickness		
Flammability Index:					
Hygroscopicity: %					
Volatility:					

Booster Sensitivity Test: <u>Nitromethane</u> Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc	Decomposition Equation: (d) <u>Nitromethane</u> Oxygen, atoms/sec $10^{14.6}$ (Z/sec) Heat, kilocalorie/mole 56.6 (ΔH , kcal/mol) Temperature Range, °C 380-430 Phase Gaseous
Heat of: (a) Combustion, cal/gm 2830 Explosion, cal/gm Gas Volume, cc/gm Formation, cal/gm -348 Fusion, cal/gm Vaporization, cal/gm 149	Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bombs: Plate Thickness, inches 1 1¼ 1½ 1¾
Specific Heat: cal/gm/°C (b) $C_p = 0.4209 - 0.00076t + 0.0000061t^2$ for 15°C to 70°C	
Burning Rate: cm/sec	Bomb Drop Test: T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete: Max Safe Drop, ft 500-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order 1000-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order
Thermal Conductivity: cal/sec/cm/°C	
Coefficient of Expansion: Linear, %/°C Volume, %/°C	
Hardness, Mohs' Scale:	
Young's Modulus: E', dynes/cm ² E, lb/inch ² Density, gm/cc	
Compressive Strength: lb/inch ²	
Vapor Pressure: (c) °C mm Mercury 70 258 85 444	

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Color: Light yellow
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Principal Uses: Minefield clearing
	Method of Loading: Pumping
	Loading Density: gm/cc <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;"> $\frac{100}{1.14}$ </div> <div style="text-align: center;"> $\frac{95/5}{1.12}$ </div> </div>
	Storage: Method Components stored separately; mixed only when ready to use Hazard Class (Quantity-Distance) Compatibility Group Exudation
	<div style="display: flex; justify-content: space-between;"> <div> <u>Minimum Propagating Thickness, in:</u> </div> <div style="text-align: center;"> $\frac{100}{0.5}$ </div> <div style="text-align: center;"> $\frac{95/5}{0.063}$ </div> </div> <div style="display: flex; justify-content: space-between; margin-top: 10px;"> <div> <u>Viscosity, centipoises:</u> </div> <div style="text-align: center;"> (e) </div> </div> <div style="display: flex; justify-content: space-between; margin-top: 10px;"> <div> Temp, 10°C 25°C 40°C </div> <div style="text-align: center;"> 0.748 0.625 0.533 </div> </div> <div style="margin-top: 10px;"> <u>Compatibility with Metals:</u> Stainless steel, mild steel and duriron not affected; corrodes brass. </div>

Origin:

Nitromethane has been known since 1872 (Kolbe, J prakt Chem (2) 5, 427 (1872), but was available only as a laboratory product until it appeared as an industrial chemical in 1940. A number of patents have been issued for nitromethane produced as a by-product of the nitration of propane (U. S. Patent 1,967,667 (1934); British Patent 443,707 (1937); and Canadian Patent 371,007 (1938).

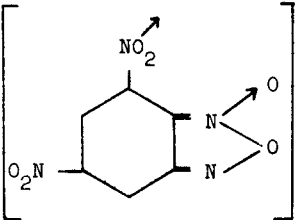
The development of nitromethane liquid explosives was based on information that nitromethane is sensitized to initiation and propagation of detonation by the addition of various amines. This study made at Picatinny Arsenal in 1945 indicated that mixtures of nitromethane with 5% of ethylenediamine, n-butyl-amine, or morpholine showed considerable promise for application in mine-field clearance (L. H. Eriksen and J. W. Rowen, PATR No. 1565, 17 September 1945).

References:⁶³

- (a) D. E. Holcomb and C. F. Dorsey, "Thermodynamic Properties of Nitroparaffins," Ind Engr Chem 41, 2788 (1949).
- (b) J. W. Williams, "A Study of the Physical Properties of Nitromethane," J Am Chem Soc 47, 2644 (1925).
- (c) L. Medard, "Explosive Properties of Nitromethane," Mem poudr 33, 125 (1951).
- (d) T. L. Cottrell, T. E. Graham and T. J. Reid, "The Thermal Decomposition of Nitromethanes," Transactions of the Faraday Society 47, 584 (1951).
- (e) F. Bellinger, H. B. Friedman, W. H. Bauer, J. W. Eastes and W. C. Bull, "Chemical Propellants: Stability of Mononitromethane," Ind Engr Chem 40, 1320 (1948).
- (f) Also see the following Picatinny Arsenal Technical Reports on Nitromethane:

<u>0</u>	<u>1</u>	<u>3</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
1660	1681 1831	2113	1565	2016	1747	1708	1619

⁶³See footnote 1, page 10.

Composition: % C 27.3 H 0.4 N 21.2 O 36.3 K 14.8 C/H Ratio 0.416				Molecular Weight: ($\text{KC}_6\text{H}_4\text{N}_4\text{O}_6$) 225
		Oxygen Balance: CO ₂ % -60 CO % -18		
		Density: gm/cc 2.21		
		Melting Point: °C Explodes 210		
		Freezing Point: °C		
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm -- Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 3; (1 lb wt) 6 Sample Wt, mg 7		Boiling Point: °C		
		Refractive Index, n_{20}^D n_{25}^D n_{30}^D		
Friction Pendulum Test: Steel Shoe Explodes Fiber Shoe Explodes		Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C		
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected		200 Gram Bomb Sand Test: Sand, gm 44.8 43.6 Black powder fuse 9.5		
Explosion Temperature: °C Seconds, 0.1 (no cap used) -- 1 -- 5 250 10 15 20		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.30 0.20 Lead Azide 0.10 Tetryl		
		Ballistic Mortar, % TNT:		
		Trouzi Test, % TNT:		
75°C International Heat Test: % Loss in 48 Hrs		Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT		
100°C Heat Test: % Loss, 1st 48 Hrs 0.03 % Loss, 2nd 48 Hrs 0.05 Explosion in 100 Hrs None		Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second		
Flammability Index:				
Hygroscopicity: % 30°C, 75% RH 0.11 30°C, 90% RH 0.27				
Volatility:				

Booster Sensitivity Test: Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc	Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH , kcal/mol) Temperature Range, °C Phase
Heat of: Combustion, cal/gm 2209 Explosion, cal/gm 725 Gas Volume, cc/gm 604 Formation, cal/gm Fusion, cal/gm	Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bombs: Plate Thickness, inches 1 1¼ 1½ 1¾
Specific Heat: cal/gm/°C (b) $\frac{^{\circ}\text{C}}{^{\circ}\text{C}}$ -50 0.217 0 0.217 25 0.217 50 0.217	Bomb Drop Test: T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete: Max Safe Drop, ft 500-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order 1000-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order
Burning Rate: cm/sec	
Thermal Conductivity: cal/sec/cm/°C	
Coefficient of Expansion: Linear, %/°C Volume, %/°C	
Hardness, Mohs' Scale:	
Young's Modulus: E', dynes/cm ² E, lb/inch ² Density, gm/cc	
Compressive Strength: lb/inch ²	
Vapor Pressure: °C mm Mercury	

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones Hole Volume Hole Depth
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Color:

Preparation of Potassium Salt of 4,6-dinitrobenzfuroxan: (a)

Benzfuroxan, made by the reaction of ortho-nitroaniline and alkaline sodium hypochlorite, was dissolved in 6 parts of 96% sulfuric acid and nitrated at 5^o-20^oC with a 4 to 1 sulfuric-nitric acid mixture. The salt was prepared by neutralization of the 4,6-dinitrobenzfuroxan with potassium bicarbonate followed by recrystallization from hot water. The product forms in small golden orange plates which explode at 210^oC.

Origin:

The potassium salt of 4,6-dinitrobenzfuroxan was first prepared in 1899 by von P. Drost (Ann 307, 56 (1899)).

References: ⁶⁴

(a) R. J. Gaughran, J. P. Picard and J. V. R. Kaufman, "Contribution to the Chemistry of Benzfuroxan Derivatives," J Am Chem Soc 76, 2233 (1954).

(b) C. Lenchitz, Ice Calorimeter Determination of Enthalpy and Specific Heat of Eleven Organometallic Compounds, PATR No. 2224, November 1955.

(c) Also see the following Picatinny Arsenal Technical Reports on Potassium Dinitrobenzfuroxan:

<u>2</u>	<u>3</u>	<u>6</u>	<u>2</u>
2122	2093	2146	2179

⁶⁴See footnote 1, page 10.

Composition: % RDX 30 Tetryl 50 TNT 20 C/H Ratio	Molecular Weight: 252	
	Oxygen Balance: CO ₂ % -45 CO % -9	
	Density: gm/cc 1.68	
	Melting Point: °C Eutectic 67	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 44 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	Boiling Point: °C	
	Refractive Index, n_{20}^D n_{25}^D n_{30}^D	
Explosion Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 3.0 120°C 135°C 150°C	
Rifle Bullet Impact Test: Trials Explosions % 20 Portals 20 Burned 0 Unaffected 60	200 Gram Bomb Sand Test: Sand, gm 54.8	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.23* Lead Azide 0.22* Tetryl *Alternative initiating charges.	
75°C International Heat Test: % Loss in 48 Hrs	Ballistic Mortar, % TNT: (a) 132	
	Trauzl Test, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Plate Dent Test: (b) Method B Condition Cast Confined No Density, gm/cc 1.68 Brisance, % TNT 127	
Flammability Index:	Detonation Rate: Confinement None Condition Cast Charge Diameter, in. 1.0 Density, gm/cc 1.64 Rate, meters/second 7655	
Hygroscopicity: % 30°C, 90% RH, 15 days 0.00		
Volatility:		

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc 1.64 Charge Wt, lb 2.180 Total No. of Fragments: For TNT 703 For Subject HE 999 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc 1.63 Charge Wt, lb 0.864 Total No. of Fragments: For TNT 514 For Subject HE 685	Shaped Charge Effectiveness, TNT = 100: <div> Glass Cones Steel Cones </div> Hole Volume Hole Depth
Fragment Velocity: ft/sec At 9 ft 2690 At 25½ ft 2460 Density, gm/cc 1.64	Color: Principal Uses: Land mines and demolition charges
Blast (Relative to TNT): Air: (a) Peak Pressure 111 Impulse 109 Energy -- Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Method of Loading: Cast Loading Density: gm/cc 1.68
Booster Sensitivity Test: (c) <div> Condition Pressed Cast </div> Tetryl, gm 100 100 Wax, in. for 50% Detonation 1.94 1.82 Density, gm/cc 1.61 1.68	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation Exudes at 65°C
	Preparation: The ternary explosive system consisting of RDX, tetryl and TNT is prepared by adding the appropriate weight of water-wet RDX to a tetrytol (40/60) previously melted in a steam-jacketed melt kettle. Heating and stirring are continued until all the water is evaporated and the mixture is uniform in composition. PTX-1 is also prepared by adding tetryl to RDX Composition B. Compatibility with Metals: <u>Dry:</u> Aluminum, mild steel not affected. <u>Wet:</u> Aluminum, mild steel not affected.

Origin:

The possibility of employing ternary mixtures to obtain explosives having greater power and higher brisance than binary mixtures was suggested by the analysis of Russian 76 mm, armor piercing high explosive rounds (PATR No. 1311, 17 July 1943). The Russian type ternary explosives, based on the composition and laboratory studies of such mixtures, were indicated to be effective pressed fillers. In conducting a preliminary study of castable ternary explosive mixtures suggested by the Russian fillers, a mixture consisting of RDX/tetryl/TNT, designated PTX-1 was developed which had explosive and physical properties offering considerable advantage for military applications (PATR No. 1360, 27 October 1943; and 1379, 11 January 1944).

A PTX-3 composition, prepared by the addition of Haleite to 40/60 tetrytol, also offered promise but limited to applications where the charge would not be required to withstand storage at 65°C without exudation.

References:⁶⁵

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (c) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.
- (d) W. R. Tomlinson, Jr., Blast Effects of Bomb Explosives, PA Tech Div Lecture, 9 April 1948.
- (e) Also see the following Picatinny Arsenal Technical Reports on PTX-1:

<u>0</u>	<u>2</u>	<u>3</u>	<u>6</u>	<u>7</u>	<u>9</u>
1530	1402	1623	1466	1437	1379
			1506		1429
					1469

⁶⁵See footnote 1, page 10.

Composition: % RDX 44 - 41 PETN 28 - 26 TNT 28 - 33 C/H Ratio	Molecular Weight: 244 243	
	Oxygen Balance: CO ₂ % -33 -36 CO % - 3 - 4	
	Density: gm/cc 1.70	
	Melting Point: °C Eutectic 75	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 35 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	Boiling Point: °C	
	Refractive Index, n ₂₀ ^D n ₂₅ ^D n ₃₀ ^D	
Friction Pendulum Test: Steel Shoe Crackles Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 2.6 120°C 11+ 135°C 150°C	
Rifle Bullet Impact Test: Trials % Explosions 60 Partials 0 Burned 0 Unaffected 40	200 Gram Bomb Sand Test: Sand, gm 56.9	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.21 Lead Azide 0.00 Tetryl 0.00	
	Ballistic Mortar, % TNT: (a) 138	
75°C International Heat Test: % Loss in 48 Hrs	Trauzl Test, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Plate Dent Test: (b) Method B Condition Cast Confined No Density, gm/cc 1.71 Brisance, % TNT 141	
	Detonation Rate: Confinement None Condition Cast Charge Diameter, in. 1.0 Density, gm/cc 1.70 Rate, meters/second 8065	
Flammability Index:		
Hygroscopicity: % 30°C, 90% RH, 15 days 0.00		
Volatility:		

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc 1.68 Charge Wt, lb 2.226 Total No. of Fragments: For TNT 703 For Subject HE 1128 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc 1.70 Charge Wt, lb 0.897 Total No. of Fragments: For TNT 514 For Subject HE 750	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones Hole Volume ~ 130 Hole Depth
Fragment Velocity: ft/sec At 9 ft 3020 At 25½ ft 2850 Density, gm/cc 1.70	Color:
Blast (Relative to TNT): Air: (d) Peak Pressure 113 Impulse 113 Energy -- Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Principal Uses: Shaped charges Fragmentation charges
Booster Sensitivity Test: (c) Condition Pressed Cast Tetryl, gm 100 100 Wax, in. for 50% Detonation 1.87 2.32 Density, gm/cc 1.70 1.61	Method of Loading: Cast
	Loading Density: gm/cc 1.70
	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation None at 65°C
	Preparation: The ternary explosive system consisting of RDX, PETN and TNT is prepared by adding the appropriate weight of water-wet RDX to a pentolite (30/70) previously melted in a steam-jacketed melt kettle. Heating and stirring are continued until all the water is evaporated and the mixture is uniform in composition. PTX-2 is also prepared by adding water-wet PETN to RDX Composition B. Compatibility with Metals: <u>Dry:</u> Aluminum, mild steel not affected. <u>Wet:</u> Aluminum not affected.

Origin:

The possibility of employing ternary mixtures to obtain explosives having greater power and higher brisance than binary mixtures was suggested by the analysis of Russian 76 mm, armor-piercing high explosive rounds (PATR No. 1311, 17 July 1943). The Russian type ternary explosives, based on the composition and laboratory studies of such mixtures, were indicated to be effective pressed fillers. In conducting a preliminary study of castable ternary explosive mixtures suggested by the Russian fillers, a mixture consisting of RDX/PETN/TNT, designated PTX-2 was developed which had explosive and physical properties offering considerable advantage for military applications (PATR No. 1360, 27 October 1943; and 1379, 11 January 1944).

A PTX-4 composition, prepared by the addition of Haleite to 30/70 Pentolite, also offered promise but because of border-line stability in accelerated stability tests, PTX-4 must be proven by long term storage to be acceptable for use in standard ammunition.

References:⁶⁶

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(c) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.

(d) W. R. Tomlinson, Jr., Blast Effects of Bomb Explosives, PA Tech Div Lecture, 9 April 1948.

(e) Also see the following Picatinny Arsenal Technical Reports on PTX-2:

<u>0</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>8</u>	<u>9</u>
1530	1482	1483	1414	1445	1466	1838	1379
		1623					1429
							1469

⁶⁶See footnote 1, page 10.

Composition:			Molecular Weight: 217		
% RDX 90 Polyvinyl Acetate 8 Dibutylphthalate 2 C/H Ratio			Oxygen Balance: CO ₂ % -37 CO % -10		
			Density: gm/cc Pressed 1.60		
			Melting Point: °C Softening Point: °C 92		
			Freezing Point: °C		
Impact Sensitivity, 2 Kg Wt:			Boiling Point: °C		
Bureau of Mines Apparatus, cm 39 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 9 Sample Wt, mg 13			Refractive Index, n ₂₀ ^D n ₂₅ ^D n ₃₀ ^D		
Friction Pendulum Test:			Vacuum Stability Test:		
Steel Shoe Crackles Fiber Shoe Unaffected			cc/40 Hrs, at 90°C 100°C 0.45 120°C 0.88 135°C -- 150°C 11+		
Rifle Bullet Impact Test: 5 Trials *			200 Gram Bomb Sand Test:		
Explosions % 20 Partials 0 Burned 60 Unaffected 20 *100 trials at -46°C - Unaffected			Sand, gm 58.5		
Explosion Temperature: °C			Sensitivity to Initiation:		
Seconds, 0.1 (no cap used) -- 1 330 5 Decomposes 375 10 265 15 20			Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.22 Tetryl		
75°C International Heat Test:			Ballistic Mortar, % TNT:		
% Loss in 48 Hrs			Trauzl Test, % TNT:		
100°C Heat Test:			Plate Dent Test:		
% Loss, 1st 48 Hrs 0.10 % Loss, 2nd 48 Hrs 0.06 Explosion in 100 Hrs None			Method Condition Confined Density, gm/cc Brisance, % TNT		
Flammability Index:			Detonation Rate:		
Hygroscopicity: % 30°C, 90% RH 0.20			Confinement None Condition Cast Charge Diameter, in. 1.0 Density, gm/cc 1.60 Rate, meters/second 7910		
Volatility: 55°C, vacuo, 6 hrs 0.03					

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Color: White Principal Uses: Demolition charges
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Method of Loading: Pressed or extruded Loading Density: gm/cc 1.60 Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation None at 71°C
	Plasticity: <div style="display: flex; justify-content: space-around;"> -40°C Cracked </div> <div style="display: flex; justify-content: space-around;"> 25°C 0.3 </div>

Preparation:

Explosive FVA-4, a semi-plastic composition of Canadian origin, consists of 90% RDX, 8% polyvinyl acetate and 2% dibutylphthalate (DBP). This formulation was developed by Dr. Sutherland of Shawinigan Chemicals, Ltd. In evaluating various types of polyvinyl acetate commercially available in the United States, a type obtained from Union Carbide and Carbon, under the industrial named or designation "AYAT" was the most promising coating for RDX in the proportions RDX/FVA(AYAT)/DBP 92/6/2.

A practical method of preparing this composition was by the addition of a solution of the coating agent to an aqueous RDX slurry. Based on the quality of the product and the pellet densities obtained, a procedure of adding an acetone solution of FVA + DBP to a hot water slurry of RDX, under agitation, was adopted as standard.

References:⁶⁷

- (a) See the following Picatinny Arsenal Technical Reports on FVA-4: 1532 and 1634.

⁶⁷See footnote 1, page 10.

Composition: % C 27 H 3.4 N 15.6 O 54 C/H Ratio 0.203 $\left(\text{H}_2\text{C} \begin{array}{c} \\ \text{CH-ONO}_2 \end{array} \right)_n$	Molecular Weight: $(\text{C}_2\text{H}_3\text{NO}_3)_n$ $(89)_n$		
	Oxygen Balance: CO ₂ % -45 CO % -9		
	Density: gm/cc		
	Melting Point: °C (Soft Pb) 50		
	Freezing Point: °C		
Impact Sensitivity, 2 Kg Wt: 14.86%N Bureau of Mines Apparatus, cm -- Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 4 Sample Wt, mg	Boiling Point: °C		
	Refractive Index, n_{20}^D n_{25}^D n_{30}^D		
	Friction Pendulum Test: Steel Shoe Crackles Fiber Shoe Unaffected		
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 16 hours 11+ 120°C 16 hours 11+ 135°C 150°C		
	200 Gram Bomb Sand Test: Sand, gm 49.9		
	Explosion Temperature: °C Seconds, 0.1 (no cap used) -- 1 -- 5 265 10 15 20		
75°C International Heat Test: % Loss in 48 Hrs 100°C Heat Test: % Loss, 1st 48 Hrs 1.9 % Loss, 2nd 48 Hrs 2.1 Explosion in 100 Hrs None	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate -- Lead Azide Tetryl		
	Ballistic Mortar, % TNT:		
	Trauzl Test, % TNT:		
Flammability Index: Hygroscopicity: % 30°C, 90% RH 0.62 Volatility:	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT		
	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second		

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Principal Uses: Method of Loading: Loading Density: gm/cc
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Storage: Method Hazard Class (Quantity-Distance) Compatibility Group Exudation <u>65.5°C KI Test:</u> <div style="display: flex; justify-content: space-between;"> Minutes 60+ </div> <u>134.5°C Heat Test:</u> <div style="display: flex; justify-content: space-between;"> <u>Minutes</u> </div> <div style="display: flex; justify-content: space-between;"> Salmon Pink 20 </div> <div style="display: flex; justify-content: space-between;"> Red Fumes 25 </div> <div style="display: flex; justify-content: space-between;"> Explodes 300+ </div> <u>240-Hour Hydrolysis Test:</u> <div style="display: flex; justify-content: space-between;"> % HNO₃ 5.07 </div> <u>Heat of:</u> <div style="display: flex; justify-content: space-between;"> Combustion, cal/gm 2960 </div> <div style="display: flex; justify-content: space-between;"> Explosion, cal/gm 900 </div> <div style="display: flex; justify-content: space-between;"> Gas Volume, cc/gm 838 </div>

Preparation:

Polyvinyl alcohol is mixed with acetic anhydride. The mixture is cooled to -5°C and the nitric acid is added slowly while the mass is being stirred. The temperature is controlled by the rate of acid addition so that when all the acid has been added the temperature does not rise above 20°C .

When the nitration is complete, the mixture is drowned by allowing a fine stream of the syrupy liquid to flow from the nitrator and mix intimately with a large stream of water. This causes the product to precipitate in a fine state.

The finely divided precipitate is purified by boiling in frequent changes of water.

Origin:

The first preparation of polyvinyl nitrate was reported in 1929 by solution of polyvinyl alcohol in concentrated sulfuric acid and treatment with nitrating acid at a temperature not over 50°C . (German Patent 537,303). Later patents issued relative to polyvinyl nitrate included U. S. Patent 2,118,487 (1938) and German Patent 737,199 (1943).

AMCP 706-177

RIPE

Composition: RDX 85 Gulf Crown E Oil 15 C/H Ratio	Molecular Weight: 230	
	Oxygen Balance: CO ₂ % -70 CO % -35	
	Density: gm/cc Hand tamped 1.37	
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 53 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 13 Sample Wt, mg 25	Boiling Point: °C	
	Refractive Index, n ₂₀ ^D n ₂₅ ^D n ₃₀ ^D	
	Vacuum Stability Test: cc/40 Hrs, at 90°C -- 100°C 0.34 120°C 0.56 135°C 150°C	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	200 Gram Bomb Sand Test: Sand, gm 40.1	
Ball Bullet Impact Test: Trials % Explosions 0 Partials 0 Burned 0 Unaffected 100	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl	
	Ballistic Mortar, % TNT: (a) 118	
	Trauzl Test, % TNT:	
	Plate Dent Test: (b) Method B Condition Hand tamped Confined No Density, gm/cc 1.37 Brisance, % TNT 85	
	Detonation Rate: Confinement None Condition Hand tamped Charge Diameter, in. 1.0 Density, gm/cc 1.37 Rate, meters/second 7390	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes; no value obtained 10 15 20	75°C Accelerational Heat Test: % Loss in 48 Hrs	
100°C Heat Test: % Loss, 1st 48 Hrs 0.03 % Loss, 2nd 48 Hrs 0.04 Explosion in 100 Hrs None	Flammability Index:	
Hygrometricity: % 30°C, 90% RH 0.04	Volatility:	

<p>Fragmentation Test:</p> <p>90 mm HE, M71 Projectile, Lot WC-91:</p> <p>Density, gm/cc 1.36</p> <p>Charge Wt, lb 1.766</p> <p>Total No. of Fragments:</p> <p>For TNT 703</p> <p>For Subject HE 592</p> <p>3 inch HE, M42A1 Projectile, Lot KC-5:</p> <p>Density, gm/cc 1.42</p> <p>Charge Wt, lb 0.756</p> <p>Total No. of Fragments:</p> <p>For TNT 514</p> <p>For Subject HE 501</p> <p>Fragment Velocity: ft/sec</p> <p>At 9 ft 2650</p> <p>At 25½ ft 2370</p> <p>Density, gm/cc 1.395</p>	<p>Shaped Charge Effectiveness, TNT = 100:</p> <p>Glass Cones Steel Cones</p> <p>Hole Volume</p> <p>Hole Depth</p> <p>Color: White</p> <p>Principal Uses: Plastic demolition explosive</p> <p>Method of Loading: Hand tamped</p> <p>Loading Density: gm/cc 1.37</p>
<p>Blast (Relative to TNT):</p> <p>Air:</p> <p>Peak Pressure</p> <p>Impulse</p> <p>Energy</p> <p>Air, Confined:</p> <p>Impulse</p> <p>Under Water:</p> <p>Peak Pressure</p> <p>Impulse</p> <p>Energy</p> <p>Underground:</p> <p>Peak Pressure</p> <p>Impulse</p> <p>Energy</p> <p><u>Preparation:</u></p> <p>RIPE is manufactured by simple mechanical mixing of RDX in oil.</p>	<p>Storage:</p> <p>Method Dry</p> <p>Hazard Class (Quantity-Distance) Class 9</p> <p>Compatibility Group Group I</p> <p>Exudation None at 85°C in 30 hrs None at 95°C in 48 hrs Exudes at 105°C in 48 hrs</p> <p><u>Origin:</u></p> <p>RIPE, a mechanical mixture of RDX and Gulf Crown E Oil, was developed in the United States during World War II.</p> <p><u>References:</u>⁶⁸</p> <p>(a) L. C. Smith and E. G. Eyster, <u>Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests</u>, OSRD Report No. 5746, 27 December 1945.</p> <p>(b) D. P. MacDougall, <u>Methods of Physical Testing</u>, OSRD Report No. 803, 11 August 1942.</p> <p>(c) Also see the following Picatinny Arsenal Technical Reports on RIPE: 1713, 1695 and 1517.</p>

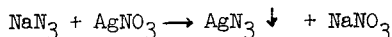
⁶⁸See footnote 1, page 10.

AMCP 706-177

Silver Azide

Composition: % N 28.0 Ag 72.0 Ag-N=N≡N C/H Ratio	Molecular Weight: (AgN ₃) 150	
	Oxygen Balance: CO ₂ % -5 CO % -5	
	Density: gm/cc Crystal 5.1	
	Melting Point: °C (a) 251 Decomposes rapidly above melting point to silver and nitrogen.	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 6 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 3 Sample Wt, mg 18	Boiling Point: °C	
	Refractive Index, n ₂₀ ^D n ₂₅ ^D n ₃₀ ^D	
Friction Pendulum Test: PA Small Apparatus Steel Shoe Detonates Fiber Shoe Detonates	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm (b) Black powder fuse 18.9	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 310 1 -- 5 Explodes 290 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	
	Ballistic Mortar, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs	Trauzl Test, % Hg(ONC) ₂ (c) 88	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
Flammability Index:		
Hygroscopicity: % (b) 25°C, 100% RH 0.04		
Volatility: 75°C, 24 hrs 0.00		

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: White to gray Principal Uses: Initiators Method of Loading: Pressed Loading Density: gm/cc Variable														
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: <div> Method Wet </div> <div> Hazard Class (Quantity-Distance) Class 9 </div> <div> Compatibility Group Group M </div> <div> Exudation None </div>														
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy <u>Explosive Power:</u> (f) <div> Kilogram meters 192,000 </div> <div> % Mercury Fulminate 1.097 </div>	<u>Initiating Efficiency:</u> <div> Grams Required to Give (c) </div> <div> Complete Initiation of TNT 0.02-0.05 </div> <u>Solubility in 100 gm Solvent at Room Temperature:</u> <table> <tr> <th>Solvent</th><th>Grams</th></tr> <tr> <td>Water (b)</td><td>0.006</td></tr> <tr> <td>Ammonium hydroxide</td><td>Soluble</td></tr> <tr> <td>Nitric acid</td><td>Decomposes</td></tr> <tr> <td>Ether (b)</td><td>0.017</td></tr> <tr> <td>Ethyl alcohol, 95%</td><td>0.006</td></tr> <tr> <td>Acetone</td><td>0.015</td></tr> </table> <div> Unaffected by water and CO₂. (d) </div> Heat of: <div> Explosion, cal/gm (c, d) 452 </div> <div> Formation, cal/gm (e) 67.8 </div>	Solvent	Grams	Water (b)	0.006	Ammonium hydroxide	Soluble	Nitric acid	Decomposes	Ether (b)	0.017	Ethyl alcohol, 95%	0.006	Acetone	0.015
Solvent	Grams														
Water (b)	0.006														
Ammonium hydroxide	Soluble														
Nitric acid	Decomposes														
Ether (b)	0.017														
Ethyl alcohol, 95%	0.006														
Acetone	0.015														

Preparation:

Prepare the following aqueous solutions:

- a. 5% NaN_3 , sodium azide, 50 cc
- b. 25% AgNO_3 , silver nitrate, 25 cc

The silver nitrate solution is placed in a 200 cc conductive rubber beaker equipped with a hard wood stirrer operated by an air motor. The sodium azide solution is placed in a separatory funnel fastened in a ring stand above the beaker containing the silver nitrate. A long cord (10 ft) is fastened to the stopcock of the separatory funnel so that the funnel can be emptied by remote control. The silver nitrate solution is now stirred very rapidly and the sodium azide is slowly run into the nitrate solution. Stirring is continued for 5 minutes. The contents of the beaker are filtered through folded filter paper and washed free of sodium azide and silver nitrate with distilled water.

Silver azide should be stored under water in a conductive rubber container. This preparation will yield approximately 7 grams.

The preparation should be conducted under a hood and behind a barricade. The product obtained by the above procedure has a very fine particle size, almost colloidal. Very fine silver azide is safer to handle and is just as efficient and stable as the large, coarse crystalline material (Ref b). When a thin film of fine silver azide is precipitated on mercury fulminate, teteryl, etc., these substances are as efficient weight for weight as pure silver azide (Ref g). White silver azide is less affected by light than mercury or lead azide (Ref h). Long colorless crystals which explode on breaking are obtained from ammonium hydroxide.

Origin:

Silver azide was first prepared in 1890-1 by T. Curtius (Ber 23, 3032; Ber 24, 3344-5) by passing hydrazoic acid (HN_3) into neutral silver nitrate solution. Taylor and Rinkensbach prepared pure "colloidal" aggregates and showed its sensitivity depends upon its particle size (Army Ordnance 5, 824 (1925)). Silver azide was found in a detonator of foreign ammunition for the first time in 1945 (Ref i).

References:⁶⁹

- (a) A. R. Hitch, "Thermal Decomposition of Certain Inorganic Trinitrides," J Am Chem Soc 40, 1195 (1918).
- (b) C. A. Taylor and Wm. H. Rinkensbach, "Silver Azide: An Initiator of Detonation," Army Ordnance, Vol 5, p. 824 (1925).
- (c) E. De W. S. Colver, High Explosives, London and New York, p. 527.
- (d) A. Stettbacher, Spreng u. Schiesstoffe, Rascher, Zurich, p. 97 (1948).
- (e) A. Marshall, Explosives, 2nd Ed, Vol II, p. 767, London.
- (f) A. Stettbacher, Z ges Schiess-Sprengstoffw 10, pp. 193-214 (1915).

⁶⁹See footnote 1, page 10.

- (g) F. Blechta, Chim et Ind Special No. 921-5 (June 1933); C. A. 28, 646.
- (h) L. Wohler and W. Krupko, Berichte 46, 2047-2050 (1913).
- (i) F. G. Haverlak, Examination of 120/45 MM HE Shell, Italian (FMAM-464), PATR No. 1515,
10 April 1945.

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Tetracene

Composition: %		Molecular Weight: (C ₂ H ₈ N ₁₀ O) 188	
C 12.8 H 4.3 N 74.4 O 8.5		Oxygen Balance: CO ₂ % -60 CO % -43	
$ \begin{array}{c} \text{NH} \quad \quad \quad \text{NH} \\ \parallel \quad \quad \quad \parallel \\ \text{C}-\text{NH}-\text{NH}-\text{N} \equiv \text{N}-\text{C} \\ \quad \quad \quad \quad \quad \quad \\ \text{NH}_2 \quad \quad \quad \quad \quad \quad \text{NH}-\text{NH}-\text{NO} \end{array} $		Density: gm/cc At 3000 psi 1.05	
C/H Ratio 0.068		Melting Point: °C Explodes 140-160	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 7 Sample Wt 20 mg Picatinny Arsenal Apparatus, in.2; (8 oz wt) 8 Sample Wt, mg		Freezing Point: °C	
Friction Pendulum Test: Steel Shoe Fiber Shoe		Boiling Point: °C	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected		Refractive Index, n ₂₀ ^D n ₂₅ ^D n ₃₀ ^D	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 160 10 15 20		Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C	
75°C International Heat Test: % Loss in 48 Hrs 0.5		200 Gram Bomb Sand Test: Sand, gm 28.0 Black powder fuse 4.0	
100°C Heat Test: % Loss, 1st 48 Hrs 23.2 % Loss, 2nd 48 Hrs 3.4 Explosion in 100 Hrs None		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.40 Lead Azide Tetryl	
Flammability Index:		Ballistic Mortar, % TNT:	
Hygroscopicity: % 30°C, 90% RH 0.77		Trauzl Test, % TNT: (a) 61	
Volatility:		Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
		Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Pale yellow Principal Uses: Priming compositions and detonators
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Method of Loading: Pressed Loading Density: gm/cc At 3000 psi 1.05
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Storage: <div> Method Wet </div> <div> Hazard Class (Quantity-Distance) Class 9 </div> <div> Compatibility Group Group M </div> Exudation <u>Solubility:</u> Practically insoluble in water, alcohol, acetone, ether, benzene, carbontetrachloride or ethylenedichloride. Sensitivity to Electrostatic Discharge, Joules: (b) <div> Unconfined 0.010 </div> <div> Confined 0.012 </div> <u>Heat of:</u> <div> Explosion, cal/gm 658 </div> <div> Gas Volume, cc/gm 1190 </div> <u>Initiating Efficiency:</u> Tetracene is not efficient in initiating high explosives.

TetracenePreparation:

(Rinkenbach and Burton, Army Ordnance 12, 120 (1931)).

Tetracene is prepared by dissolving 5 gms of aminoguanidine dinitrate in 30 cc of water, cooling to 0°C and mixing with a solution of 2.5 gms of sodium nitrate in 15 cc of water. The temperature is maintained at about 10°C and 0.5 gm of acetic acid is added. The tetracene separates out and is washed with water, alcohol and ether. It is then dried.

Tetracene may also be prepared by placing aminoguanidine sulphate and sodium nitrite in a large beaker and adding water heated to 30°C. The heat of reaction causes the mixture to boil; after standing for two or three hours the separated tetracene is filtered off, washed thoroughly and dried.

Origin:

Tetracene was first prepared in 1910 by Hoffman and Roth (Ber 43, 682) who also studied its chemical reactions and determined its structure (Hoffman et al, Ber 43, 1087, 1866 (1910); Ber 44, 2496 (1911); and Ann 380, 131 (1911)). W. H. Rinkenbach and O. Burton made an extensive study of tetracene and described its manufacture and explosive properties (Army Ordnance 12, 120 (1931)).

Destruction by Chemical Decomposition:

Tetracene is decomposed by adding it to boiling water and continuing boiling for some time to insure complete decomposition.

References:⁷⁰

(a) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

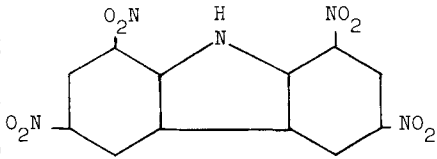
L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) F. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.

(c) Also see the following Picatinny Arsenal Technical Reports on Tetracene:

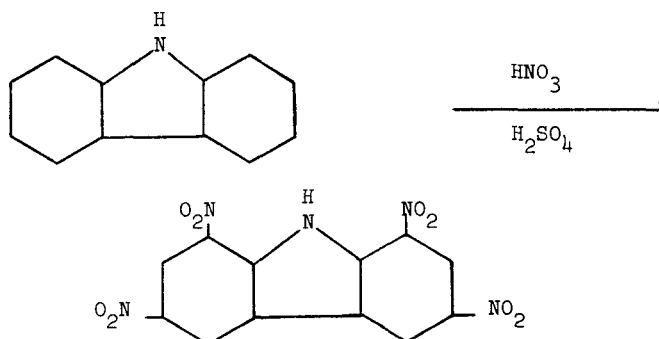
<u>0</u>	<u>1</u>	<u>3</u>	<u>4</u>	<u>7</u>	<u>8</u>	<u>9</u>
1450	11	453	1104 2164	407	318	859 2179

⁷⁰See footnote 1, page 10.

Composition: % C 41.6 H 1.4 N 20.0 O 37.0 C/H Ratio 1.032		Molecular Weight: ($C_{12}H_5N_5O_8$) 347	
		Oxygen Balance: CO ₂ % -85 CO % -30	
		Density: gm/cc	
		Melting Point: °C Pure 1,3,6,8-isomer 296	
		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 100+ Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 18 Sample Wt, mg 14		Boiling Point: °C	
		Refractive Index, n_{20}^D n_{25}^D n_{30}^D	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected		Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.2 120°C 0.2 135°C 150°C	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected		200 Gram Bomb Sand Test: Sand, gm 41.3	
Explosion Temperature: °C Seconds, 0.1 (no cap used) -- 1 -- 5 Decomposes 470 10 15 20		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate -- Lead Azide 0.20 Tetryl 0.25	
75°C International Heat Test: % Loss in 48 Hrs		Ballistic Mortar, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs 0.15 % Loss, 2nd 48 Hrs 0.05 Explosion in 100 Hrs None		Trauzl Test, % TNT:	
Flammability Index:		Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
Hygroscopicity: % 30°C, 90% RH 0.01		Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
Volatility:			

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones Hole Volume Hole Depth																
	Color: Light yellow																
	Principal Uses: Component of igniter and pyrotechnic compositions																
	Method of Loading: Pressed																
	Loading Density: gm/cc																
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Exudation																
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Solubility in Water, gm/100 gm (%), at: 95°C 0.10 <u>Qualitative Solubilities:</u> <table><tr><td><u>Solvent</u></td><td><u>Solubility</u></td></tr><tr><td>Nitrobenzene</td><td>Very soluble</td></tr><tr><td>Acetone</td><td>Soluble</td></tr><tr><td>Benzene</td><td>Insoluble</td></tr><tr><td>Chloroform</td><td>Insoluble</td></tr><tr><td>Carbontetrachloride</td><td>Insoluble</td></tr><tr><td>Ether</td><td>Insoluble</td></tr><tr><td>Ether, petroleum</td><td>Insoluble</td></tr></table>	<u>Solvent</u>	<u>Solubility</u>	Nitrobenzene	Very soluble	Acetone	Soluble	Benzene	Insoluble	Chloroform	Insoluble	Carbontetrachloride	Insoluble	Ether	Insoluble	Ether, petroleum	Insoluble
<u>Solvent</u>	<u>Solubility</u>																
Nitrobenzene	Very soluble																
Acetone	Soluble																
Benzene	Insoluble																
Chloroform	Insoluble																
Carbontetrachloride	Insoluble																
Ether	Insoluble																
Ether, petroleum	Insoluble																

Preparation:



Sulfonation: Fifty-six gms of carbazole is dissolved in 320 gms of H_2SO_4 (96%, specific gravity 1.84). The solution is agitated during the addition of the carbazole and the temperature maintained at $25^\circ\text{--}35^\circ\text{C}$. After the addition of the carbazole is completed, the agitation is continued and solution completed by raising the temperature to $80^\circ\text{--}85^\circ\text{C}$ and maintaining this temperature for one hour. The sulphate is now cooled to 20°C .

Nitration: The sulfonate solution is slowly added to 168 gms of HNO_3 (Plant grade specific gravity 1.525 at 15°C) maintaining the temperature at 30° to 50°C . (Time required - 1 hour 25 minutes). The temperature is then gradually raised to 70° to 75°C and maintained for one hour after which the temperature is raised to 85° to 90°C and held for one hour, then lowered to room temperature before drowning.

Drowning: The nitration mixture is drowned by pouring it into 2 to 3 volumes of ice and water.

Filtering: The separated light yellow product is filtered on a Buchner Funnel and washed with water twice to remove most of the acid.

Purification: The TNC is placed in hot water (95° to 100°C) and boiled for five to ten minutes with rapid agitation, allowed to settle then filtered and washed once. This procedure is repeated twice, making a total of three "boilings." The final wash is acid free.

Drying: The TNC is spread in a thin layer and dried at 100° to 110°C for four hours.

Yield: 73.3%.

Melting Point of TNC as prepared: 280°C (compares to 296°C for pure 1,3,6,8-isomer in preceding data).

Origin:

The preparation of Tetranitrocarbazole (TNC) was first reported in 1880 by C. Graebe (Ann 202, 26 (1880)) who nitrated carbazole with 94% nitric acid. Similar procedures were followed by R. Escales (Ber 37, 3596 (1904)) and P. Zierch (Ber 42, 3800 1909). However, G. L. Ciamician and P. P. Silber observed the formation of four isomeric TNC's when acetyl carbazole was treated with fuming nitric acid (Gazz chim ital 12, 272 1882). In 1912 and 1913 patents were issued to the dyestuff manufacturer, Casella and Company, covering the preparation of polynitrocarbazoles (German Patent 268,173 and French Patent 464,538). The Casella process of

preparing polynitrocarbazoles by dissolving carbazole in sulfuric acid and treating the solution of sulfonic acids with strong nitrating agents is essentially the process used today in the United States. The crude product, thus prepared, contains principally 1,3,6,8-TNC (W. Borsche and B. G. B. Scholten Ber 50, 596 (1917) and about 10% of the 1,2,6,8-TNC isomer (D. B. Murphy et al J Am Chem Soc 75, 4289 (1953). TNC was used in explosives by the Germans during World War II.

References:⁷¹

(a) D. B. Murphy, F. R. Schwartz, J. P. Picard and J. V. R. Kaufman, "Identification of Isomers Formed in the Nitration of Carbazole," J Am Chem Soc, 75, 4289-4291 (1953).

(b) S. Livingston, Preparation of Tetranitrocarbazole, PA Chemical Research Laboratory Report No. 136,330, 11 April 1951.

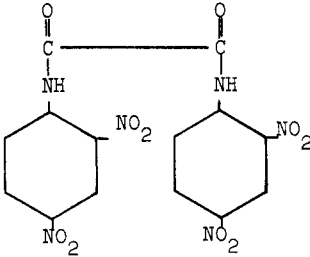
(c) D. B. Murphy et al, Long Range Basic Technical Research Leading to the Development of Improved Ignition Type Powders - The Chemistry of Tetranitrocarbazole, PA Memorandum Report No. 22, 2 September 1952.

(d) S. Livingston, Development of Improved Ignition Type Powders, PATR No. 2267, July 1956.

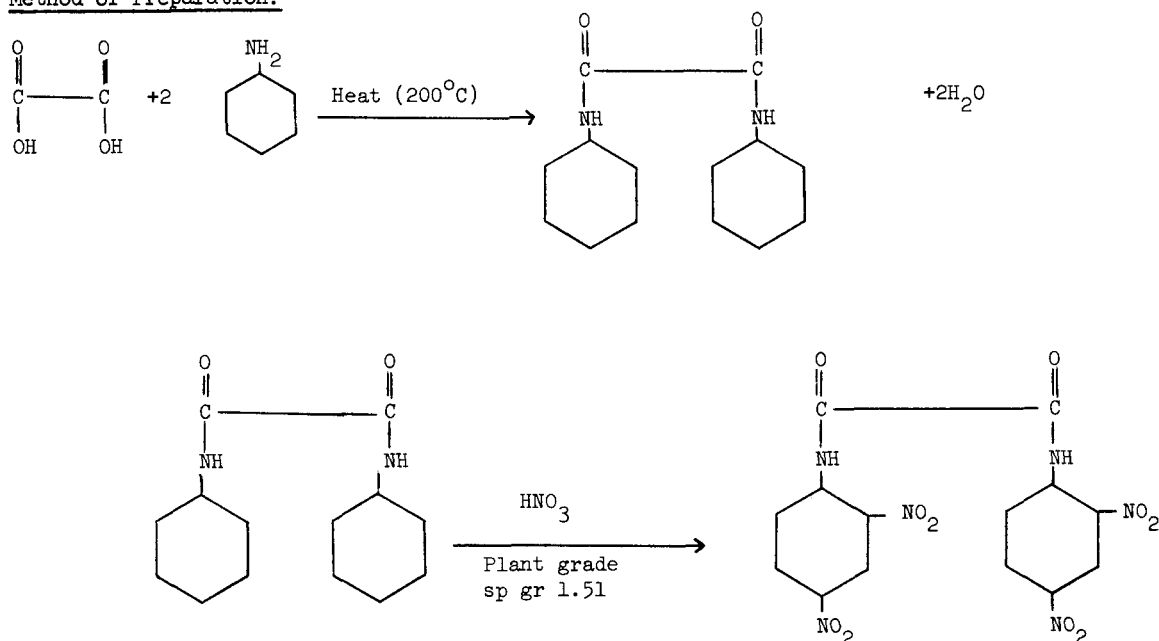
(e) Also see the following Picatinny Arsenal Technical Reports on Tetranitrocarbazole:

<u>0</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>7</u>
2180	1802	1973	1984	1647 1937

⁷¹See footnote 1, page 10.

Composition: % C 40.0 H 1.9 N 20.0 O 38.1 C/H Ratio 0.735				Molecular Weight: ($C_{14}H_8N_6O_{10}$) 420
		Oxygen Balance: CO ₂ % -84 CO % -31		
		Density: gm/cc		
		Melting Point: °C Decomposes 313		
		Freezing Point: °C		
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm -- Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 30 Sample Wt, mg 11		Boiling Point: °C		
		Refractive Index, n_{20}^D n_{25}^D n_{30}^D		
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected		Vacuum Stability Test: cc/40 Hrs, at 90°C -- 100°C -- 120°C 0.11 135°C 150°C		
Rifle Bullet Impact Test: Trials % Explosions Partial Burned Unaffected		200 Gram Bomb Sand Test: Sand, gm 16.3		
Explosion Temperature: °C Seconds, 0.1 (no cap used) -- 1 -- 5 392 10 15 20		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.25		
75°C International Heat Test: % Loss in 48 Hrs		Ballistic Mortar, % TNT:		
100°C Heat Test: % Loss, 1st 48 Hrs 0.07 % Loss, 2nd 48 Hrs 0.00 Explosion in 100 Hrs None		Trauzl Test, % TNT:		
Flammability Index:		Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT		
Hygroscopicity: % 30°C, 90% RH Trace		Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second		
Volatility:				

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones Hole Volume Hole Depth
	Color: Light yellow
	Principal Uses: Component of black powder type and pyrotechnic compositions
	Method of Loading: Pressed and extruded compositions
	Loading Density: gm/cc
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Exudation
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	<u>Solubility, gm/100 cc Solvent, in:</u> °C % Water 100 <0.10 Nitrobenzene 150 >15 <u>Qualitative Solubilities:</u> <u>Solvent</u> <u>Solubility</u> Ethyl alcohol Insoluble Benzene Insoluble Butyl acetate Insoluble Carbontetrachloride Insoluble Ethyl ether Insoluble Acetic acid Soluble Nitric acid Soluble Caustic potash Soluble Dimethyl formamide Very soluble

Method of Preparation:Oxanilide:

Two parts of oxalic acid are mixed with one part of aniline in a round bottom flask. The mixture is stirred and heated until the reaction is complete as evidenced by the cessation of effervescence. The mass is cooled to room temperature, poured into several volumes of water (21°-24°C), filtered on a Büchner funnel and washed free of oxalic acid with water and then washed free of aniline with acetone. The oxanilide is air dried to remove the acetone and then dried at 100°-110°C.

Tetranitro-oxanilide (TNO):

A 5 liter round bottom flask is equipped with a stirrer of a type which will produce a downward "swirl." The flask is surrounded with a water jacket for hot and cold water. Fifteen hundred grams (1.5 kilograms) of 98% plant grade nitric acid is placed into the flask. Five hundred (500) grams of oxanilide is slowly added to the acid under rapid agitation while the temperature is maintained below 40°C. After the addition of the oxanilide is completed (2½-3 hrs), the agitation is continued 10-15 minutes. The temperature is then raised to 80°C over a period of one hour and maintained at 80°-85°C for 3 hours. The acid slurry is then cooled to room temperature and drowned by pouring over cracked ice. The product is filtered on a Büchner funnel and washed with water until it is almost acid free. The filter cake is placed in a beaker and sufficient water added to form a "slurry." Live steam is run into the "slurry" under agitation for 10 minutes. The slurry is filtered and the residue washed. The latter treatment of the "slurry" is repeated until the wash water is found to be neutral to

litmus paper. The TNO is washed with alcohol, then acetone, air dried and finally dried at 100°-110°C.

Yield = 90% to 97.5% of theoretical.

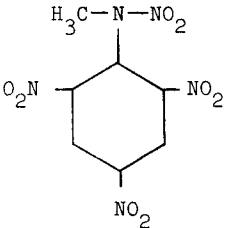
Origin:

A. G. Perkin in 1892 obtained tetranitro-oxanilide directly by heating a solution of finely powdered oxanilide in nitric acid. He also obtained the same compound by the action of a cooled mixture of nitric and sulfuric acids on oxanilide and precipitating the product by pouring the solution into water (J Chem Soc 61, 460 (1892)).

References:⁷²

- (a) S. Livingston, Development of Improved Ignition Type Powders, PATR No. 2267, July 1956.
- (b) D. Dubrow and J. Kristal, Substitution of Tetranitro Oxanilide and Hexanitro Oxanilide for Tetranitro Carbazole, PA Pyrotechnic Research Laboratory Report 54-TF 1-88, 20 December 1954.

⁷²See footnote 1, page 10.

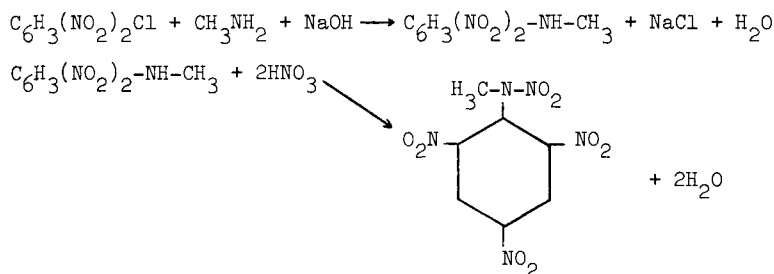
Composition: % C 29.3 H 1.7 N 24.4 O 44.6 C/H Ratio 0.420				Molecular Weight: (C ₇ H ₅ N ₅ O ₈) 287
		Oxygen Balance: CO ₂ % -47 CO % -8		
		Density: gm/cc Crystal 1.73		
		Melting Point: °C 130		
		Freezing Point: °C		
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 26 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 8 Sample Wt, mg 18		Boiling Point: °C		
		Refractive Index, n _D ²⁰ n _D ²⁵ n _D ³⁰		
Friction Pendulum Test: Steel Shoe Crackles Fiber Shoe Unaffected		Vacuum Stability Test: cc/40 Hrs, at 90°C -- 100°C 0.3 120°C 1.0 135°C -- 150°C 11+		
Rifle Bullet Impact Test: Trials Explosions % 13 Partial 54 Burned 10 Unaffected 23		200 Gram Bomb Sand Test: Sand, gm 54.2		
Explosion Temperature: °C Seconds, 0.1 (no cap used) 340 1 314 5 Ignites 257 10 238 15 236 20 234		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.20* Lead Azide 0.10* Tetryl *Alternative initiating charges.		
		Ballistic Mortar, % TNT: (a) 130		
		Trauzl Test, % TNT: (b) 125		
75°C International Heat Test: % Loss in 48 Hrs 0.01		Plate Dent Test: (c) Method A B Condition Pressed Pressed Confined Yes No Density, gm/cc 1.50 1.59 1.36 Brisance, % TNT 116 115 96		
100°C Heat Test: % Loss, 1st 48 Hrs 0.1 % Loss, 2nd 48 Hrs 0.0 Explosion in 100 Hrs None		Detonation Rate: Confinement None Condition Pressed Charge Diameter, in. 1.0 Density, gm/cc 1.71 Rate, meters/second 7850		
Flammability Index: 244				
Hygroscopicity: % 30°C, 90% RH 0.04				
Volatility: 25°C 0.00				

Booster Sensitivity Test: Condition (d) Pressed Tetryl, gm 100 Wax, in. for 50% Detonation 2.01 Wax, gm Density, gm/cc 1.58	Decomposition Equation: Oxygen, atoms/sec (g) 10 ^{15.4} (h) 10 ^{12.9} (Z/sec) Heat, kilocalorie/mole 38.4 34.9 (ΔH, kcal/mol) Temperature Range, °C 211-260 132-164 Phase Liquid Liquid
Heat of: Combustion, cal/gm 2925 Explosion, cal/gm 1080-1130 Gas Volume, cc/gm 760 Formation, cal/gm -14 Fusion, cal/gm °C (e) 22.2 Temperature, °C 127	Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bombs: Plate Thickness, inches 1 1¼ 1½ 1¾
Specific Heat: cal/gm/°C (e) °C -100 0.182 - 50 0.200 0 0.212 50 0.223 100 0.236	
Burning Rate: cm/sec	
Thermal Conductivity: (f) cal/sec/cm/°C 5.81 x 10 ⁻⁴ at 1.394 gm/cc 6.83 x 10 ⁻⁴ at 1.528 gm/cc	Bomb Drop Test: T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete: Max Safe Drop, ft 500-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order 1000-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order
Coefficient of Expansion: Linear, %/°C Volume, %/°C	
Hardness, Mohs' Scale:	
Young's Modulus: E', dynes/cm ² E, lb/inch ² Density, gm/cc	
Compressive Strength: lb/inch ²	
Vapor Pressure: °C mm Mercury	

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc 1.58 Charge Wt, lb 2.052 Total No. of Fragments: For TNT 703 For Subject HE 864 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc 1.62 Charge Wt, lb 0.848 Total No. of Fragments: For TNT 514 For Subject HE 605	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Light yellow Principal Uses: Boosters; ingredient of explosive mixtures, detonators, and blasting caps Method of Loading: Pressed Loading Density: gm/cc See below
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group L Exudation Does not exude at 65°C
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	<div style="border-top: 1px solid black; padding-top: 10px;"> Loading Density: gm/cc <div style="display: flex; justify-content: space-around;"> Cast 1.62 Pressed </div> <div style="display: flex; justify-content: space-around;"> <div>psi x 10³</div> <div>0 3 5 10 12 15 20</div> <div>0.9 1.40 1.47 1.57 1.60 1.63 1.67</div> </div> <div style="display: flex; justify-content: space-around; margin-top: 10px;"> <div>30</div> <div>1.71</div> </div> </div> <div style="border-top: 1px solid black; padding-top: 10px;"> Effect of Temperature on Rate of Detonation: (j) <div style="display: flex; justify-content: space-around;"> <div>16 hrs at, °C</div> <div>-54</div> <div>21</div> </div> <div style="display: flex; justify-content: space-around;"> Density, gm/cc </div> <div style="display: flex; justify-content: space-around;"> 1.52 1.53 </div> <div style="display: flex; justify-content: space-around;"> Rate, m/sec </div> <div style="display: flex; justify-content: space-around;"> 7150 7170 </div> </div>

TetrylPreparation:

(Manufacture of Tetryl by Dinitromonomethylaniline Process, Wannamaker Chemical Co., Inc.)



To a solution of 202.5 gm dinitrochlorobenzene in 200 cc benzene, at 75°C with good agitation, in 15 to 20 minutes, add 112 gm of 30% aqueous monomethylamine. Then add 129 gm of 31% aqueous sodium hydroxide, in 15 to 20 minutes, at such a rate as to cause refluxing; continue agitation for 3 hours at 70°C. The mixture is concentrated to a liquid temperature of 101°-102°C, cooled, filtered and the precipitate washed with distilled water until the washings give no test with silver nitrate, dried at 60°C (melting point 167.2°C).

The dinitromethylaniline is nitrated to tetryl by solution of it in 88% sulfuric acid (197 gm nitroaniline/1190 gm sulfuric) at 25°C, followed by addition of nitric acid. The process is carried out so that the water content remains at 16%. Solution (per 197 gm nitroaniline) requires 5 to 10 minutes, nitration, by addition of the sulfuric acid solution to nitric acid, about 1 hour at 30°C, plus 48 minutes at 50° to 55°C at the end. The mixture is then cooled to 20°C and filtered. The tetryl is dumped into 1 liter water, washed 2 or 3 times with 200 cc cold water, and then stirred 10 to 15 minutes at 50°C with 500 cc water, filtered warm and then washed with water until the washings are neutral to methyl orange. The tetryl dried to constant weight at 70°C weighs about 270 gm.

Tetryl filtered from an acid containing 87% sulfuric acid (or more) -13% water, at 40°C (or over) may fire in 30 minutes to 1 hour and 30 minutes, if not drowned in water. A safe nitration procedure, even on plant scale involves:

1. The concentration of sulfuric in the spent acid is maintained at a low level (approx 80/1.8/18.2 sulfuric/nitric/water).
2. Nitration maximum temperature is 50°C.
3. The slurry is cooled to 35°C before filtration.
4. Filtration time prior to drowning, is minimized (15 minutes maximum).

The crude tetryl produced is recrystallized to remove impurities and occluded acid and to control its granulation.

Tetryl

Sensitivity of tetryl electrostatic discharge, joules; through 100 mesh: (i)

Unconfined	0.007
Confined	4.4

Solubility of tetryl, grams in 100 grams (%) of:

<u>Water</u>		<u>Carbon tetrachloride</u>		<u>Ether</u>		<u>95% Alcohol</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
0	0.0050	0	0.007	0	0.188	0	0.320
20	0.0075	20	0.015	10	0.330	10	0.425
40	0.0110	40	0.058	20	0.418	20	0.563
80	0.0810	60	0.154	30	0.493	30	0.76
100	0.184					50	1.72
						75	5.33

<u>Chloroform</u>		<u>Carbon disulfide</u>		<u>Ethylene dichloride</u>		<u>Acetone</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
0	0.28	0	0.009	25	4.5	20	75
20	0.39	10	0.015	75	45	30	95
40	1.20	20	0.021			40	116
60	2.65	30	0.030			50	138

<u>Trichloroethylene</u>		<u>Ethyl acetate</u>		<u>Benzene</u>		<u>Toluene</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
0	0.07	20	~ 40	20	7.8	20	8.5
20	0.12			30	10.0		
40	0.26			40	12.5		
60	0.67			50	16.0		
80	1.50						
86	1.76						

<u>Xylene</u>		<u>TNT</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
20	3.3	80	82
30	4.4	100	149
40	5.4	120	645
50	6.0		

Origin:

Tetryl was first described in 1879 by Michler and Meyer (Ber 12, 1792), van Romburgh and Martens studied its properties and proved its structure (Rec trav chim 2, 108 (1883); 6, 215 (1887); and Ber 19, 2126 (1886)). Tetryl was not used as an explosive until World War I.

TetrylDestruction by Chemical Decomposition:

Tetryl is decomposed by dissolving in 12 times its weight of a solution prepared from 1 part by weight of sodium sulfite ($\text{Na}_2\text{SO}_3 \cdot 7\text{H}_2\text{O}$) in 4 parts water. The sulfite solution may be heated to 80°C to facilitate decomposition of the Tetryl.

References:⁷³

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) Ph Naoum, Z ges Schiess---Sprengstoffw, pp. 181, 229, 267 (27 June 1932).

(c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(d) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303; 15 June 1949.

(e) C. A. Taylor and Wm. H. Rinckenbach, "The Solubility of Trinitro-Phenylmethyl-Nitramine (Tetryl) in Organic Solvents," J Am Chem Soc 45, (1923) p. 104.

(f) E. Hutchinson, The Thermal Sensitiveness of Explosives. The Thermal Conductivity of Explosive Materials, AC 2861, First Report, August 1942.

(g) R. J. Finkelstein and G. Gamow, Theory of the Detonation Process, NAVORD Report No. 90-46, 20 April 1947.

(h) M. A. Cook and M. T. Abegg, "Isothermal Decomposition of Explosives," University of Utah, Ind Eng Chem 1090-1095 (June 1956).

(i) J. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.

(j) W. F. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Different Temperatures, PATR No. 2383, November 1956.

(k) Also see the following Picatinny Arsenal Technical Reports on Tetryl:

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
30	11	132	453	84	65	266	117	28	129
600	361	582	493	144	195	556	197	438	179
770	381	832	623	294	425	786	637	628	319
810	621	882	833	314	525	986	707	708	609
1180	861	1192	863	694	565	1086	807	788	709
1290	1041	1352	1113	774	625	1126	837	838	849
1350	1131	1372	1373	784	635	1316	857	1418	999
1360	1261	1402	2053	874	845	1376	1047	1788	1029
1400	1311	1452	2163	904	925	1416	1137	1828	1209
1450	1431	1592	2233	1134	1145	1446	1287	1838	1379
1500	1471			1164	1285	1466	1337		1429
1510	1611			1234	1405	1556	1367		1489
1670	1651			1264	1585	1636	1437		1819
				2024	1885	1956	1737		1969
				2204	1935		1797		
					2105		1937		
					2125				
					2205				

⁷³See footnote 1, page 10.

Composition:			Molecular Weight: 274		
% Tetryl 80 TNT 20 C/H Ratio			Oxygen Balance: CO ₂ % -52 CO % -11		
			Density: gm/cc Cast 1.51		
			Melting Point: °C 68		
			Freezing Point: °C		
Impact Sensitivity, 2 Kg Wt:			Boiling Point: °C		
Bureau of Mines Apparatus, cm 28 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 9 Sample Wt, mg 17			Refractive Index, n_{20}^D n_{25}^D n_{30}^D		
Friction Pendulum Test:			Vacuum Stability Test:		
Steel Shoe Fiber Shoe			cc/40 Hrs, at 90°C 100°C 3.0 120°C 11+ 135°C 150°C		
Rifle Bullet Impact Test: Trials			200 Gram Bomb Sand Test:		
Explosions % 0 Partials 20 Burned 0 Unaffected 80			Sand, gm 54.0		
Explosion Temperature: °C			Sensitivity to Initiation:		
Seconds, 0.1 (no cap used) 1 5 Ignites 290 10 15 20			Minimum Detonating Charge, gm Mercury Fulminate 0.22* Lead Azide 0.17* Tetryl *Alternative initiating charges.		
75°C International Heat Test:			Ballistic Mortar, % TNT:		
% Loss in 48 Hrs			Trauzl Test, % TNT:		
100°C Heat Test:			Plate Dent Test:		
% Loss, 1st 48 Hrs 0.1 % Loss, 2nd 48 Hrs 0.5 Explosion in 100 Hrs None			Method Condition Confined Density, gm/cc Brisance, % TNT		
Flammability Index: Will not continue to burn			Detonation Rate:		
Hygroscopicity: % 0.02			Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second		
Volatility:					

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Color: Light yellow to buff
	Principal Uses: Bursting, demolition blocks
	Method of Loading:
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Loading Density: gm/cc
	Storage: <div style="display: flex; justify-content: space-between;"> Method Dry </div> <div style="display: flex; justify-content: space-between;"> Hazard Class (Quantity-Distance) Class 9 </div> <div style="display: flex; justify-content: space-between;"> Compatibility Group Group I </div> <div style="display: flex; justify-content: space-between;"> Exudation Exudes at 65°C </div>

Composition: % Tetryl75 TNT25 C/H Ratio	Molecular Weight: 270	
	Oxygen Balance: CO ₂ % -54 CO % -12	
	Density: gm/cc	Cast1.59
	Melting Point: °C68	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm28 Sample Wt 20 mg Picatinny Arsenal Apparatus, in.10 Sample Wt, mg17	Boiling Point: °C	
	Refractive Index, n ₂₀ ^D n ₂₅ ^D n ₃₀ ^D	
	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C3.0 120°C11+ 135°C 150°C	
Friction Pendulum Test: Steel ShoeCracks Fiber ShoeUnaffected	200 Gram Bomb Sand Test: Sand, gm53.7	
Rifle Bullet Impact Test: Trials % Explosions0 Partials30 Burned0 Unaffected70	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate0.23* Lead Azide0.19* Tetryl *Alternative initiating charges.	
	Ballistic Mortar, % TNT: (a)122	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Ignites310 10 15 20	Trauzl Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: (b) MethodB ConditionCast ConfinedNo Density, gm/cc1.66 Brisance, % TNT118	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Detonation Rate: ConfinementNone ConditionCast Charge Diameter, in.1.0 Density, gm/cc1.60 Rate, meters/second7385	
Flammability Index: Will not continue to burn		
Hygroscopicity: %	0.03	
Volatility:		

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc 1.59 Charge Wt, lb 2.101 Total No. of Fragments: For TNT 703 For Subject HE 857 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc 1.60 Charge Wt, lb 0.845 Total No. of Fragments: For TNT 514 For Subject HE 591 Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones (d) Hole Volume 127 Hole Depth 120 Color: Light yellow to buff Principal Uses: Burstlers, demolition blocks Method of Loading: Cast Loading Density: gm/cc 1.59 Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation Exudes at 65°C <u>Eutectic Temperature, °C:</u> 67.5 gm Tetryl/100 gm TNT 67.5°C 54-82 <u>Booster Sensitivity Test:</u> (c) Condition Cast Tetryl, gm 100 Wax, in. for 50% Detonation 1.66 Density, gm/cc 1.66
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Composition: % Tetryl 70 TNT 30 C/H Ratio	Molecular Weight: 266	
	Oxygen Balance: CO ₂ % -55 CO % -13	
	Density: gm/cc	Cast 1.60
	Melting Point: °C 68	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 28 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 11 Sample Wt, mg 18	Boiling Point: °C	
	Refractive Index, n ₂₀ ^D n ₂₅ ^D n ₃₀ ^D	
	Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	
Rifle Bullet Impact Test: Trials Explosions 0 Partial 55 Burned 0 Unaffected 45	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 3.2 120°C 11+ 135°C 150°C	
	200 Gram Bomb Sand Test: Sand, gm 53.2	
	Explosion Temperature: °C Seconds, 0.1 (no cap used) 416 1 387 5 Ignites 320 10 302 15 289 20 275	
75°C International Heat Test: % Loss in 48 Hrs	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.23* Lead Azide 0.22* Tetryl *Alternative initiating charges.	
	Ballistic Mortar, % TNT: (a) 120	
	Trauzl Test, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs 0.1 % Loss, 2nd 48 Hrs 0.1 Explosion in 100 Hrs None	Plate Dent Test: (b) Method B Condition Cast Confined Yes Density, gm/cc 1.60 Brisance, % TNT 117	
	Detonation Rate: Confinement None Condition Cast Charge Diameter, in. 1.0 Density, gm/cc 1.60 Rate, meters/second 7340	
	Flammability Index: Will not continue to burn	
Hygroscopicity: % 0.02		
Volatility:		

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc 1.60 Charge Wt, lb 2.090 Total No. of Fragments: For TNT 703 For Subject HE 840 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc 1.60 Charge Wt, lb 0.842 Total No. of Fragments: For TNT 514 For Subject HE 585	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Light yellow to buff Principal Uses: Burststers, demolition blocks Method of Loading: Cast Loading Density: gm/cc 1.60
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation Exudes at 65°C
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	

Composition: % Tetryl 65 TNT 35 C/H Ratio	Molecular Weight: 264	
	Oxygen Balance: CO ₂ % -56 CO % -14	
	Density: gm/cc 1.60	
	Melting Point: °C 68	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 28 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 11 Sample Wt, mg 17	Boiling Point: °C	
	Refractive Index, n ₂₀ ^D n ₂₅ ^D n ₃₀ ^D	
Friction Pendulum Test: Steel Shoe Cracks Fiber Shoe Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 2.8 120°C 11+ 135°C 150°C	
Rifle Bullet Impact Test: Trials % Explosions 0 Partial 10 Burned 0 Unaffected 90	200 Gram Bomb Sand Test: Sand, gm 52.6	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Ignites 325 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.23* Lead Azide 0.23* Tetryl *Alternative initiating charges.	
75°C International Heat Test: % Loss in 48 Hrs 100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Ballistic Mortar, % TNT:	
	Trauzl Test, % TNT:	
Flammability Index: Will not continue to burn Hygroscopicity: % 0.02 Volatility:	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
	Detonation Rate: Confinement None Condition Cast Charge Diameter, in. 1.0 Density, gm/cc 1.60 Rate, meters/second 7310	

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc 1.61 Charge Wt, lb 2.010 Total No. of Fragments: For TNT 703 For Subject HE 856 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc 1.60 Charge Wt, lb 0.845 Total No. of Fragments: For TNT 514 For Subject HE 585	Shaped Charge Effectiveness, TNT = 100: <div><div>(d)</div><div>(e)</div><div>Glass ConesSteel Cones</div><div>Hole Volume133126</div><div>Hole Depth120119</div></div>
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Color: Light yellow to buff
	Principal Uses: Bursters, demolition blocks
	Method of Loading: Cast
	Loading Density: gm/cc 1.60
	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation Exudes at 65°C

Tetrytol, 80/20, 75/25, 70/30, 65/35Compatibility with Metals:

Dry: Copper, brass, aluminum, magnesium, stainless steel, mild steel, mild steel coated with acid proof black paint and mild steel plated with copper, cadmium, zinc or nickel are unaffected. Magnesium-aluminum alloy is slightly affected.

Wet: Stainless steel and mild steel coated with acid-proof black paint are unaffected. Copper, brass, aluminum, magnesium, magnesium-aluminum alloy, mild steel and mild steel plated with cadmium, copper, zinc or nickel are slightly affected.

Preparation:

Tetrytols are manufactured by heating TNT in a melting kettle, equipped with a stirrer, until all the TNT is melted. The necessary amount of tetryl is added and heating and stirring are continued. The temperature is allowed to drop from 100°C until the mixture is of maximum viscosity suitable for pouring. Part of the tetryl dissolves in TNT forming a eutectic mixture which contains 55 percent tetryl. This mixture freezes at 67.5°C.

Origin:

Tetrytols were developed during World War II. The 70/30 tetryl/TNT castable mixture is the most important in military applications.

References:⁷⁴

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III, Miscellaneous Sensitivity Tests, Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(c) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.

(d) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Sec III, Variation of Cavity Effect with Explosive Composition, NDRC Contract W672-ORD-5723.

(e) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Final Report, Eastern Lab, du Pont, 18 September 1943, NDRC Contract W-672-ORD-5723.

(f) Also see the following Picatinny Arsenal Technical Reports on Tetrytol:

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
1260	1291	1372	1193	1285	1376	1477	1158	1379
1360	1311		1213	1325	1436	1737	1388	
1420	1451		1363	1885	1466	1797	1838	
1500	1651		1493	2125	1506			
1530	1951							

⁷⁴See footnote 1, page 10.

Composition:			Molecular Weight: (C ₇ H ₅ N ₃ O ₆) 227		
%			Oxygen Balance:		
C	37.0		CO ₂ %		-74
H	2.2		CO %		-25
N	18.5		Density: gm/cc Crystal 1.65		
O	42.3		Melting Point: °C 81		
C/H Ratio	0.549		Freezing Point: °C		
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 95-100+ Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 14-15 Sample Wt, mg 17			Boiling Point: °C		
			Refractive Index, n_D²⁰		
			α		1.5430
			β		1.6742
			γ		1.717
Friction Pendulum Test:			Vacuum Stability Test:		
Steel Shoe		Unaffected	cc/40 Hrs, at		
Fiber Shoe		Unaffected	90°C		
Rifle Bullet Impact Test:			100°C		0.10
	Trials		120°C		0.23
Explosions	%		135°C		0.44
Partial	4		150°C		0.65
Burned	0		200 Gram Bomb Sand Test:		
Unaffected	6		Sand, gm		48.0
Explosion Temperature:			Sensitivity to Initiation:		
Seconds, 0.1 (no cap used)	°C		Minimum Detonating Charge, gm		
1	570		Mercury Fulminate		0.24*
5 Decomposes	520		Lead Azide		0.27*
10	475		Tetryl		
15	465		*Alternative initiating charges.		
20			Ballistic Mortar, % TNT: Std=100		
75°C International Heat Test:			Trauzl Test, % TNT: Std=100		
% Loss in 48 Hrs		0.04	Plate Dent Test:		
100°C Heat Test:			(a)		
% Loss, 1st 48 Hrs		0.2	Method	A	A B
% Loss, 2nd 48 Hrs		0.2	Condition	Cast	Pressed Cast
Explosion in 100 Hrs		None	Confined	Yes	Yes No
Flammability Index: (b) 100			Density, gm/cc	1.61	1.50 1.61
Hygroscopicity: % 30°C, 90% RH 0.03			Brisance, % TNT	100	100 100
Volatility: 30°C Nil			Detonation Rate:		
			Confinement	Unconfined	Unconfined
			Condition	Pressed	Cast
			Charge Diameter, in.	1.0	1.0
			Density, gm/cc	1.56	1.56
			Rate, meters/second	6825	6640

Booster Sensitivity Test: (c)			Decomposition Equation: (h) (i)		
Condition	Pressed	Cast	Oxygen, atoms/sec (Z/sec)	10 ^{11.4}	10 ^{12.2}
Tetryl, gm	100	100	Heat, kilocalorie/mole (ΔH, kcal/mol)	34.4	43.4
Wax, in. for 50 % Detonation	1.68	0.82	Temperature Range, °C	275-310	238-277
Wax, gm			Phase	Liquid	Liquid
Density, gm/cc	1.55	1.60			
Heat of: (d)			Armor Plate Impact Test:		
Combustion, cal/gm		3620	60 mm Mortar Projectile: (j)		
Explosion, cal/gm		1080	50 % Inert, Velocity, ft/sec		>1100
Gas Volume, cc/gm		730	Aluminum Fineness		
Formation, cal/gm		78.5	500-lb General Purpose Bombs: (j)		
Fusion, cal/gm		22.34			
Temperature, °C		79			
Specific Heat: cal/gm/°C					
°C			Plate Thickness, inches	<u>Trials</u>	<u>% Inert</u>
0		0.309	1	0	
20		0.328	1¼	0	
50		0.353	1½	4	100
80		0.374	1¾	4	50
Burning Rate:			Bomb Drop Test:		
cm/sec			T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:		
Thermal Conductivity:			Max Safe Drop, ft 5000-6000		
cal/sec/cm/°C		See next page.	500-lb General Purpose Bomb vs Concrete:		
Coefficient of Expansion: (b)				<u>No Seal</u>	<u>Seal</u>
Linear, %/°C	-40° to 60°C	5.4 x 10 ⁻⁵ (b)	Height, ft	4,000	4-5,000
	-40° to 60°C	6.7 x 10 ⁻⁵	Trials	26	20
Volume, %/°C	27° to 80°C	16 x 10 ⁻⁵ (b)	Unaffected	24	20
	16° to 70°C	26.3 x 10 ⁻⁵ (n)	Low Order	2	0
Hardness, Mohs' Scale: (e)			High Order	0	0
		1.4	1000-lb General Purpose Bomb vs Concrete:		
Young's Modulus: (b)				<u>No Seal</u>	<u>Seal</u>
E', dynes/cm ²		5.45 x 10 ¹⁰	Height, ft	5,000	5,000
E, lb/inch ²		0.79 x 10 ⁶	Trials	21	26
Density, gm/cc		161	Unaffected	18	22
Compressive Strength: lb/inch ² 13800-14000			Low Order	0	0
Density, gm/cc		1.62	High Order	3	4
Vapor Pressure: (f)					
°C	mm Mercury				
80	0.042				
85	0.053				
90	0.067				
95	0.085				
100	0.106				

Fragmentation Test:	Shaped Charge Effectiveness, TNT = 100:						
90 mm HE, M71 Projectile, Lot WC-91:	Density, gm/cc		1.60		Glass Cones		Steel Cones
	Charge Wt, lb		2.104		Hole Volume		100
					Hole Depth		100
Total No. of Fragments:							
	For TNT		703		Color: Light yellow		
	For Subject HE		703				
3 inch HE, M42A1 Projectile, Lot KC-5:							
	Density, gm/cc		1.60		Principal Uses: GP bombs, HE projectiles, demolition charges, depth charges, grenades, propellant compositions		
	Charge Wt, lb		0.848				
Total No. of Fragments:							
	For TNT		514		Method of Loading: 1. Cast		
	For Subject HE		514		2. Pressed		
Fragment Velocity: ft/sec (k)							
	At 9 ft		2600		Loading Density: gm/cc See below		
	At 25½ ft		2360				
	Density, gm/cc		1.58		Storage:		
Blast (Relative to TNT):							
Air:	Peak Pressure		100		Method		Dry
	Impulse		100		Hazard Class (Quantity-Distance)		Class 9
	Energy		100		Compatibility Group		Group I
Air, Confined:	Impulse		100		Exudation		None at 65°C
Under Water:	Peak Pressure		100		Loading Density: gm/cc		
	Impulse		100		1. Cast 1.58-1.59 2. Pressed psi x 10 ³		
	Energy		100		3 5 10 15 20 30 50		
Underground:	Peak Pressure		100		1.35 1.40 1.45 1.52 1.55 1.59 1.6		
	Impulse		100		Thermal Conductivity:		
	Energy		100		cal/sec/cm/°C		
					Density 1.19 gm/cc (g) 5.28 x 10 ⁻⁴		
					1.51 gm/cc (g) 7.12 x 10 ⁻⁴		
					1.54 gm/cc (b) 5.6 x 10 ⁻⁴		
					1.67 gm/cc (g) 12.21 x 10 ⁻⁴		
					Viscosity, poises:		
					Temp, 85°C 0.139		
					100°C 0.095		
					Bulk Modulus at Room Temperature (25°-30°C): (m)		
					Dynes/cm ² x 10 ⁻¹⁰ 2.92		
					Density, gm/cc 1.56		

Effect of Temperature on Rate of Detonation: (1)

Temperature of Charge, °C	-54	21	60	60
Hours at Temperature	16	16	24	72
Density, gm/cc	1.63	1.62	1.64	1.64
Rate, meters/second	6700	6820	6770	6510

Sensitivity to Electrostatic Discharge, Joules; Through 100 Mesh:

Unconfined	0.06
Confined	4.4

Impact Sensitivity versus Temperature:

Picatinny Arsenal Apparatus, 2 kg wt, inches:

<u>°C</u>	<u>inches</u>
-40	17
Room	14
80	7
90	3
105-110	2 (5 expl in 20 trials)

Impact Sensitivity versus Loading Method, Large Impact Apparatus, Inches:

Pressed at 1.60 gm/cc	70
Cast at 1.60 gm/cc	26

Rifle Bullet Impact Sensitivity versus Temperature, Confinement:

<u>Standard Iron Bomb:</u>	<u>Room Temperature</u>	<u>105° to 110°C</u>
No Air Space		
Trials	10	10
Explosions	1 very low order	7
Air Space		
Trials	10	10
Explosions	0	0

Tin or Cardboard Bombs:

With or Without Air Space		
Trials	10	10
Explosions	0	0

Explosion Temperature versus TNT Initial Temperature:

<u>TNT Temperature, Initial</u>	<u>Explosion Temperature, °C</u>
Room	470 (Decomposes)
105°-100°C	480 (Decomposes)

Explosion Temperature versus Confinement, °C:

Unconfined	Decomposes	470
Sealed in glass capillary	Explodes	320-335

Viscosity at 80.5°C:

Viscosity, X, cp $\log X = 0.046 S + 1.26$
 S = % solid in slurry
 Particle size effect, small

Density, gm/cc:

<u>°C</u>	<u>State</u>	<u>gm/cc</u>
27 to 70	Flaked	1.65
80	Flaked	1.64
82	Liquid	1.48
87	Liquid	1.48
95	Liquid	1.47

Solubility of TNT, gm/100 gm (%), in: (f)

<u>Water</u>		<u>Acetone</u>		<u>Benzene</u>		<u>Toluene</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
0	0.0100	0	57	0	13	0	28
20	0.0130	20	109	20	67	20	55
40	0.0285	40	228	40	180	40	130
60	0.0675	60	600	60	478	60	367
				80	>2000	80	>1700

<u>Carbon tetrachloride</u>		<u>Ether</u>		<u>Chloroform</u>		<u>Trichloroethylene</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
0	0.20	0	1.73	0	6	25	3.5
0	0.65	20	3.29	20	19	55	60
40	1.75			40	66		
60	6.90			60	302		
70	17.34						
75	24.35						

TNT (Trinitrotoluene)

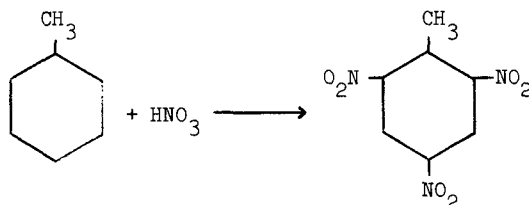
<u>Pyridine</u>		<u>Methyl acetate</u>		<u>Ethylene dichloride</u>		<u>β-Ethoxy-ethyl-acetate</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
20	140	20	73	20	34	20	29.5
40	250	40	135	40	123	40	49
60	640	50	280	60	460	50	96
70	1250						

<u>Tetrachloro-ethane</u>		<u>Aniline</u>		<u>Isopropyl alcohol</u>		<u>Ethanol</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
20	18	10	6.1	20	0.76	0	0.62
40	50	30	11.5	40	1.96	20	1.25
50	100	50	29	50	2.95	40	2.85
		70	74			60	8.4
		80	130			70	15

<u>Isobutyl alcohol</u>		<u>Carbon disulfide</u>		<u>Chlorobenzene</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
0	0.20	0	0.14	20	35
20	0.61	20	0.44	30	51
40	1.41	40	1.4	40	79
50	2.35			50	116

Preparation:

(AC 7258, 7259, 7260 - Nitration Kinetics)
 (Chemistry of Powder and Explosives, Davis)



In older processes trinitrotoluene (TNT) was slowly and laboriously nitrated in three stages using successively stronger acids. Today, however, a single stage nitration is possible, in a short time (less than one hour) producing TNT at a cost of a little less than 6¢/lb. In England, a two stage continuous process was developed during World War II; in the first counter current stage, toluene was nitrated to the mono stage mononitrotoluene (MNT); in the second stage, also counter current, MNT was nitrated to TNT.

It was the British work, on the kinetics of nitration of toluene to TNT, that first pointed out the basic importance to nitration processes of the nitroxyl ion (NO_2^+), on the one hand, and the role of the bisulfate ion (HSO_4^-) and unionized sulfuric acid on the other. These concepts were successful in explaining the maximum in nitration rate occurring at a sulfuric acid content of 92%. This work, for instance, leads to the following equation for the rate of formation of TNT from DNT:

$$\frac{d(\text{TNT})}{dt} = K (\text{NO}_2^+) [K' (\text{HSO}_4^-) + K'' (\text{H}_2\text{SO}_4)] (\text{DNT})$$

Three Stage Process: Toluene (100 gm) is nitrated to the mono derivative by slowly adding a mixture of 294 gm sulfuric acid (sp gr 1.84) and 147 gm nitric acid (sp gr 1.42) to it at 30°-40°C, with good agitation. Acid addition requires 1-1.5 hour, and stirring at 30°-40°C is continued 30 minutes longer. The mixture is cooled and the lower layer of spent acid drawn off.

Half the crude mono is dissolved in 109 gm sulfuric acid (sp gr 1.84) with cooling, the solution heated to 50°C and a mixture of 54.5 gm nitric acid (sp gr 1.50) and 54.5 gm sulfuric acid (sp gr 1.84) added, under agitation, at such a rate that the temperature is maintained between 90° and 100°C. Acid addition requires 1 hour, and stirring at 90°-100°C is continued 2 more hours.

While the dinitration mixture is still at 90°C, 145 gm fuming sulfuric acid (oleum containing 15% free SO_3) is added slowly. A mixed acid of 92.5 gm each nitric acid (sp gr 1.50) and 15% oleum is slowly added, under good agitation at 100°-115°C over 1½-2 hours. The mixture is stirred at 100°-115°C for 2 more hours, cooled, filtered, and the TNT cake broken up and washed with water. The TNT is washed 3-4 times with hot water (85°-95°C) with good agitation. The product can be purified either by recrystallization from alcohol or by washing it with 5 times its weight of 5% sodium bisulfite solution at 90°C for ½ hour with vigorous stirring, washing with hot water until the washings are colorless, and cooling slowly with stirring to granulate the product.

Origin:

TNT was first prepared in 1863 by Wilbrand (Ann 128, 178), later by Beilstein and Kuhlberg (Ber 3, 202 (1870) and also Tiemann (Ber 3, 217 (1870)), each using different methods of starting materials. It was nearly 30 years later when Hausermann undertook its manufacture on an industrial scale (Z angew Chem, 1891, p. 508; J Chem Ind, 1891, p. 1028). After 1901 TNT began to be used extensively as a military explosive and Germany became the first nation to adopt it as a standard shell filler (1902-1904). During World War I all the major powers of the world were using TNT, with the quantity used limited only by the available supply of toluene. Prior to World War II the development of synthetic toluene from petroleum made available in the United States, an almost unlimited supply of this raw material. Because of the general suitability of TNT for melt-loading and its extensive use in binary and ternary explosive mixtures, TNT is considered the most important military explosive known today.

Destruction by Chemical Decomposition:

TNT is decomposed by adding it slowly, while stirring, to 30 times its weight of a solution prepared by dissolving 1 part of sodium sulfide ($\text{Na}_2\text{S} \cdot 9\text{H}_2\text{O}$) in 6 parts of water.

References:⁷⁵

- (a) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

⁷⁵See footnote 1, page 10.

(b) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.

(c) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Teteryl in Boosters, NOL Memo 10,303, 15 June 1949.

(d) L. C. Smith and E. H. Eyster, Physical Testing of Explosives, Part III, Miscellaneous Sensitivity Tests, Performance Tests, OSRD Report No. 5746, 27 December 1945.

(e) Report AC-2587.

(f) International Critical Tables and various other sources in the open literature.

(g) E. Hutchinson, The Thermal Sensitiveness of Explosives. The Thermal Conductivity of Explosive Materials, AC-2861, First Report, August 1942.

(h) A. J. B. Robertson, Trans Farad Society, 44, 977 (1948).

(i) M. A. Cook and M. T. Abegg, "Isothermal Decomposition of Explosives," University of Utah, Ind Eng Chem (June 1956), pp. 1090-1095.

(j) Committee of Div 2 and 8, NDRC, Report on HBX and Tritonal, OSRD No. 5406, 31 July 1945.

(k) R. W. Drake, Fragment Velocity and Panel Penetration of Several Explosives in Simulated Shells, OSRD Report No. 5622, 2 January 1946.

(l) W. F. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Different Temperatures, PATR No. 2383, November 1956.

(m) W. S. Cramer, Bulk Compressibility Data on Several High Explosives, NAVORD Report No. 4380, 15 September 1956.

(n) Mantrov, Journal of Chemical Industry (Russia) 6, 1929, pp. 1686-1688.

(o) Also see the following Picatinny Arsenal Technical Reports on TNT:

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
10	291	132	43	364	65	86	47	118	99
30	551	582	83	694	195	266	87	288	249
240	731	782	133	874	425	556	507	638	269
350	861	892	273	904	555	666	527	738	319
630	891	972	513	1094	695	956	597	768	389
760	901	1072	643	1104	735	986	707	838	499
810	971	1182	673	1124	805	1046	807	1088	709
1120	1041	1192	743	1224	975	1146	817	1098	739
1140	1121	1272	853	1284	1145	1276	837	1128	779
1170	1311	1292	863	1294	1155	1376	1107	1148	799
1260	1391	1342	1063	1304	1225	1446	1147	1158	889
1270	1431	1352	1123	1314	1285	1466	1217	1188	929
1360	1451	1372	1133	1344	1305	1476	1247	1198	939
1400	1491	1402	1193	1414	1315	1556	1307	1228	1099
1460	1651	1452	1243	1444	1395	1636	1417	1258	1109
1500	1821	1472	1323	1454	1425	1756	1427	1308	1129

TNT (Trinitrotoluene)

<u>0</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
1530	1492	1373	1524	1435	1956	1437	1318	1139
1540	1562	1493	1544	1445	2216	1457	1338	1179
1550	1582	1553	1564	1495		1497	1388	1199
1730	1712	1633	1604	1515		1537	1418	1259
2010	1862	1693	1674	1535		1547	1428	1289
2100		1823	1754	1585		1557	1578	1339
2160		2063	1924	1605		1577	1618	1369
		2163	2064	1635		1597	1688	1379
			2214	1665		1677	1728	1419
				1865		1737	1828	1429
				1965		1797	1838	1469
				1715		1827	1858	1489
				1885		1847	2008	1529
				2125		2007	2138	1549
				2175		2147	2168	1629
						2167		1689
								1709
								1729
								1749
								1809
								1819
								1879
								1949
								2159
								2179

Composition:			Molecular Weight:		97
%			Oxygen Balance:		
RDX		42	CO ₂ %		-55
TNT		40	CO %		-26
Aluminum		18	Density: gm/cc		Cast 1.76-1.81
C/H Ratio			Melting Point: °C		
			Freezing Point: °C		
Impact Sensitivity, 2 Kg Wt:			Boiling Point: °C		
Bureau of Mines Apparatus, cm			Refractive Index, n ₂₀ ^D		
Sample Wt 20 mg			n ₂₅ ^D		
Picatinny Arsenal Apparatus, in.			n ₃₀ ^D		
Sample Wt, mg					
Friction Pendulum Test:			Vacuum Stability Test:		
Steel Shoe			cc/40 Hrs, at		
Fiber Shoe			90°C		
			100°C		
			120°C		1.0
			135°C		
			150°C		
Rifle Bullet Impact Test:			200 Gram Bomb Sand Test:		
Trials			Sand, gm		59.5
Explosions %					
20					
Partial 80					
Burned 0					
Unaffected 0					
Explosion Temperature:			Sensitivity to Initiation:		
°C			Minimum Detonating Charge, gm		
Seconds, 0.1 (no cap used)			Mercury Fulminate		0.18
1			Lead Azide		
5 Decomposes 260			Tetryl		
10					
15					
20					
75°C International Heat Test:			Ballistic Mortar, % TNT:		(a) 138
% Loss in 48 Hrs			Trauzl Test, % TNT:		(b) 164
			Plate Dent Test:		(c)
100°C Heat Test:			Method		B
% Loss, 1st 48 Hrs			Condition		Cast
0.00			Confined		No
% Loss, 2nd 48 Hrs			Density, gm/cc		1.83
0.10			Brisance, % TNT		120
Explosion in 100 Hrs					
None					
Flammability Index:			Detonation Rate:		(d)
196			Confinement		None
			Condition		Cast
Hygroscopicity: %			Charge Diameter, in.		1.0
30°C, 90% RH			Density, gm/cc		1.81
0.00			Rate, meters/second		7495
Volatility:					

Booster Sensitivity Test: (c) Condition Pressed Cast Tetryl, gm 10 5 Wax, in. for 50% Detonation Wax, gm 2 0 Density, gm/cc 1.64 1.81	Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH , kcal/mol) Temperature Range, °C Phase
Heat of: (a) Combustion, cal/gm 3740 Explosion, cal/gm 1800 Gas Volume, cc/gm Formation, cal/gm Fusion, cal/gm	Armor Plate Impact Test: 60 mm Mortar Projectile: (a) 50% Inert, Velocity, ft/sec 185 Aluminum Fineness 500-lb General Purpose Bombs: Plate Thickness, inches 1 1¼ 1½ 1¾
Specific Heat: cal/gm/°C (b) At -5°C 0.22 Density, gm/cc 1.82 At 15°C 0.24	Bomb Drop Test: T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete: Max Safe Drop, ft 500-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order 1000-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order
Burning Rate: cm/sec	
Thermal Conductivity: (b) cal/sec/cm/°C 9.7×10^{-4} Density, gm/cc 1.82	
Coefficient of Expansion: Linear, %/°C -73° to 75°C 4.7×10^{-5} (b) Volume, %/°C	
Hardness, Mohs' Scale:	
Young's Modulus: (b) E', dynes/cm ² 9.53×10^{10} E, lb/inch ² 1.38×10^6 Density, gm/cc 1.77	
Compressive Strength: lb/inch ² (b) 2100-2300 Density, gm/cc 1.77	
Vapor Pressure: °C mm Mercury	

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc 1.75 Charge Wt, lb 2.316 Total No. of Fragments: For TNT 703 For Subject HE 891 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc 1.79 Charge Wt, lb 0.940 Total No. of Fragments: For TNT 514 For Subject HE 647	Shaped Charge Effectiveness, TNT = 100: <u>50/36.5/13.5</u> Glass Cones Steel Cones Hole Volume 150 145 Hole Depth 127 131												
	Color: Gray												
	Principal Uses: Depth charges, bombs												
	Method of Loading: Cast												
	Loading Density: gm/cc 1.76-1.81												
Fragment Velocity: ft/sec At 9 ft 2960 At 25½ ft 2800 Density, gm/cc --	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation												
Blast (Relative to TNT): (e) Air: Peak Pressure 122 Impulse 125 Energy 146 Air, Confined: Impulse 116 Under Water: Peak Pressure 116 Impulse 127 Energy 153 Underground: Peak Pressure Impulse Energy	Effect of Temperature on Impact Sensitivity: <table><tr><th><u>Temp.</u> <u>°C</u></th><th><u>PA Impact Test</u> <u>2 Kg Wt, inches</u></th></tr><tr><td>25</td><td>15</td></tr><tr><td>32</td><td>7</td></tr><tr><td>104</td><td>8</td></tr></table> Viscosity, poises: <table><tr><td>Temp, 83°C</td><td>4.5</td></tr><tr><td>95°C</td><td>2.3</td></tr></table>	<u>Temp.</u> <u>°C</u>	<u>PA Impact Test</u> <u>2 Kg Wt, inches</u>	25	15	32	7	104	8	Temp, 83°C	4.5	95°C	2.3
<u>Temp.</u> <u>°C</u>	<u>PA Impact Test</u> <u>2 Kg Wt, inches</u>												
25	15												
32	7												
104	8												
Temp, 83°C	4.5												
95°C	2.3												

TorpexPreparation:

Torpex is manufactured by heating TNT to approximately 100°C in a steam-jacketed kettle equipped with a stirrer. Water wet RDX is added slowly to the molten TNT, while mixing and heating, until all the water is evaporated. Aluminum is added and the mixture is stirred until uniform. The mixture is cooled, with continued stirring, until it is suitable for pouring. Torpex can also be made by adding the calculated amount of TNT to Composition B to maintain the desired proportion of RDX/TNT, heating and stirring, and adding 18 percent of aluminum to complete the mixture.

Origin:

Torpex, a castable high explosive, was developed in England during World War II for use as a filler in warheads, mines and depth bombs. Several variations in the composition of torpex have been evaluated but the following are those used in service munitions:

	<u>Torpex 2</u> <u>unwaxed</u>	<u>Torpex 2</u> <u>waxed</u>	<u>Torpex 3</u>
	(a)	(b)	(c)
RDX, %	42	41.6	41.4
TNT, %	40	39.7	39.5
Aluminum, %	18	18.0	17.9
Wax, %		0.7	0.7
Calcium chloride, %			0.5

(a) Made from Composition B-2 or 60/40 Cyclotol.

(b) Made by the addition of aluminum to Composition B.

(c) Made by the addition of calcium chloride to Torpex 2.

Wax has the undesirable effect of (1) tending to coagulate the aluminum, thus giving a less homogeneous and more viscous product, (2) lowering the density of the cast explosive from 1.72-1.75 to 1.66-1.70 for waxed torpex, and (3) lowering the compressive strength from 3700 psi to 1970 psi for waxed torpex. However, wax is used in service torpex for reasons of safety, since there is evidence that its presence lowers the sensitivity of the explosive to impact as measured by laboratory drop tests and bullet sensitivity tests of small charges (Bureau of Ord Res Memo Rpt No. 24, January 1945).

References:⁷⁶

(a) Committee of Div 2 and 8, NDRC, Report on HBX and Tritonal, OSRD No. 5406, 31 July 1945.

(b) Philip C. Keenan and Dorothy C. Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.

(c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

L. C. Smith and E. H. Eyster, Physical Testing of Explosives, Part III, Miscellaneous Sensitivity Tests, Performance Tests, OSRD Report No. 5746, 27 December 1945.

⁷⁶See footnote 1, page 10.

(d) G. H. Messerly, The Rate of Detonation of Various Explosive Compounds, OSRD Report No. 1219, 22 February 1943.

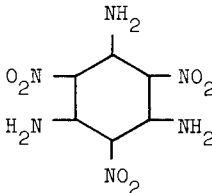
M. D. Hurwitz, The Rate of Detonation of Various Compounds and Mixtures, OSRD Report No. 5611, 15 January 1946.

(e) W. R. Tomlinson, Jr., Blast Effects of Bomb Explosives, PA Tech Div Lecture, 9 April 1948.

(f) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Sec III, Variation of Cavity Effect with Explosive Composition, NDRC Contract W672-ORD-5723.

(g) Also see the following Picatinny Arsenal Technical Reports on Torpex:

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>
1530	1651	1292	2353	1585	1796	1797	1838
				1635			
				1885			
				2355			

Composition: % C 27.9 H 2.3 N 32.6 O 37.2 C/H Ratio 0.302				Molecular Weight: (C ₆ H ₆ N ₆ O ₆) 258	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 11 Sample Wt, mg 7		Oxygen Balance: CO ₂ % -56 CO % -19		Density: gm/cc Crystal 1.93	
				Melting Point: °C 330 (b, e) 360 (a)	
				Freezing Point: °C	
Friction Pendulum Test: Steel Shoe Fiber Shoe		Boiling Point: °C		Refractive Index, n ₂₀ ^D n ₂₅ ^D n ₃₀ ^D	
				Vacuum Stability Test: cc/40 Hrs, at 90°C ---- 100°C (a, b) 0.36 120°C ---- 135°C ---- 150°C ----	
				200 Gram Bomb Sand Test: Sand, gm 42.9	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate ---- Lead Azide 0.30 Tetryl ----		Ballistic Mortar, % TNT:	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 10 15 20				Trauzl Test, % TNT:	
				Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
75°C International Heat Test: % Loss in 48 Hrs		Detonation Rate: Confinement None Condition Pressed Charge Diameter, in. 0.5 Density, gm/cc 1.80 Rate, meters/second 7500			
100°C Heat Test: % Loss, 1st 48 Hrs 0.00 % Loss, 2nd 48 Hrs 0.00 Explosion in 100 Hrs None					
Flammability Index:					
Hygroscopicity: %					
Volatility:					

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Yellow Principal Uses: Method of Loading: Pressed														
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Loading Density: gm/cc At 50,000 psi 1.80														
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Storage: Method Dry Hazard Class (Quantity-Distance) Compatibility Group Exudation Detonation Velocity: (a, b, c) <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: center;"><u>Density, gm/cc</u></th> <th style="text-align: center;"><u>Meters/sec</u></th> </tr> </thead> <tbody> <tr><td style="text-align: center;">1.290</td><td style="text-align: center;">5380</td></tr> <tr><td style="text-align: center;">1.345</td><td style="text-align: center;">5628</td></tr> <tr><td style="text-align: center;">1.675</td><td style="text-align: center;">6550</td></tr> <tr><td style="text-align: center;">1.675</td><td style="text-align: center;">6575</td></tr> <tr><td style="text-align: center;">1.882</td><td style="text-align: center;">7035</td></tr> <tr><td style="text-align: center;">1.835</td><td style="text-align: center;">7220</td></tr> </tbody> </table> Heat of: Explosion, cal/gm 2831	<u>Density, gm/cc</u>	<u>Meters/sec</u>	1.290	5380	1.345	5628	1.675	6550	1.675	6575	1.882	7035	1.835	7220
<u>Density, gm/cc</u>	<u>Meters/sec</u>														
1.290	5380														
1.345	5628														
1.675	6550														
1.675	6575														
1.882	7035														
1.835	7220														

Preparation:

(a)

Absolute alcohol (200 milliliters) was saturated with ammonia and then 12.5 gm (0.028 mol) of 1,3,5-tribromo-2,4,6-trinitrobenzene, prepared according to Hill (NAVORD Report No. 3709, 2 February 1953), was added. The flask was stoppered and allowed to stand at room temperature for a day. Additional ammonia was bubbled into the mixture, which was then heated under reflux for thirty minutes, filtered hot, and the insoluble product collected on a Buchner funnel. The product was washed with water, alcohol, and dried. The 4.7 gm of material recovered was recrystallized from nitrobenzene.

A disadvantage of the above method was that it could not be used for the preparation of large quantities of TATNB. Since it did not seem feasible to develop a new method of preparation, an investigation was made of the reported amination reactions (see Origin below). An attempt was made (Ref f) to find a modification which would produce high yields of a pure product. The process which evolved from this study may be summarized as follows (Ref f): 1,3,5-trichlorobenzene was nitrated "in one step" to 1,3,5-trichloro-2,4,6-trinitrobenzene in 85% yield. The crude nitration product was aminated in benzene with ammonia gas to TATNB, in yields of at least 95%.

Origin:

TATNB was prepared for the first time in 1888 by C. L. Jackson and J. F. Wing, who found the compound insoluble in alcohol, ether, chloroform, benzene, and glacial acetic acid; and soluble in nitrobenzene and aniline (Amer Chem Journal 10, 282 (1888)). B. Flurschein and E. L. Holmes prepared TATNB from benzene free pentanitroaniline by gradually adding it to 10% aqueous ammonia (J Chem Soc, Pt 2, 3045 (1928)). After boiling, an orange-yellow powder melting above 300°C was obtained. This product corresponded to that described by Jackson and Wing. These authors, as well as Palmer (Amer Chem Journal 14, 378 (1892)), attempted to reduce TATNB to hexa-aminobenzene. Either decomposition occurred or a hydrochloride of penta-aminobenzene was formed. Flurschein and Holmes succeeded in reducing TATNB with phenylhydrazine by heating them together up to 200°C (J Chem Soc, Pt 1, 334 (1929)) (Beil 13, 301 and EII, 147).

References:⁷⁷

(a) F. Taylor, Jr., Synthesis of New High Explosives II, Derivatives of 1,3,5-Tribromo-2,4,6-Trinitrobenzene, NAVORD Report No. 4405, 1 November 1956.

(b) L. D. Hampton, Small Scale Detonation Velocity Measurements from May 1951 to May 1954, NAVORD Report No. 3731, June 1954.

(c) E. M. Fisher and E. A. Christian, Explosion Effects Data Sheets, NAVORD Report No. 2986, 14 June 1955.

⁷⁷See footnote 1, page 10.

Composition: % C 29.9 H 5.4 N 11.7 O 53.0 C/H Ratio 0.177		<chem>CCOC(=O)COC(=O)COC(=O)C</chem>		Molecular Weight: ($C_6H_{12}N_2O_8$) 240
		Oxygen Balance: CO ₂ % -89 CO % -27		
		Density: gm/cc 20°C 1.33 25°C 1.32		
		Melting Point: °C		
		Freezing Point: °C		
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 100+ Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 43 Sample Wt, mg		Boiling Point: °C		
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected		Refractive Index, n_{20}^D 1.4540 n_{25}^D n_{30}^D		
Rifle Bullet Impact Test: Trials % Explosions Partial Burned Unaffected		Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 8 hours 0.45 135°C 0.8 150°C		
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 223 10 15 20		200 Gram Bomb Sand Test: Sand, gm 14.7		
75°C International Heat Test: % Loss in 48 Hrs		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl		
100°C Heat Test: % Loss, 1st 48 Hrs 1.8 % Loss, 2nd 48 Hrs 1.6 Explosion in 100 Hrs None		Ballistic Mortar, % TNT:		
Flammability Index:		Trauzl Test, % TNT:		
Hygroscopicity: %		Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT		
Volatility: 60°C, mg/cm ² /hr 40		Detonation Rate: Confinement Shelby steel Condition Liquid Charge Diameter, in. 1.25 Density, gm/cc 1.33 Rate, meters/second Fails		

<p>Fragmentation Test:</p> <p>90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments: For TNT For Subject HE</p> <p>3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments: For TNT For Subject HE</p>	<p>Shaped Charge Effectiveness, TNT = 100:</p> <p>Glass Cones Steel Cones</p> <p>Hole Volume Hole Depth</p> <p>Color:</p> <p>Principal Uses: Ingredient of rocket and double base propellants</p> <p>Method of Loading:</p> <p>Loading Density: gm/cc</p>
<p>Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc</p>	<p>Storage:</p> <p>Method Liquid</p> <p>Hazard Class (Quantity-Distance)</p> <p>Compatibility Group</p> <p>Exudation</p>
<p>Blast (Relative to TNT):</p> <p>Air: Peak Pressure Impulse Energy</p> <p>Air, Confined: Impulse</p> <p>Under Water: Peak Pressure Impulse Energy</p> <p>Underground: Peak Pressure Impulse Energy</p>	<p><u>Solubility in Water,</u> <u>gm/100 gm, at:</u></p> <p>25°C 0.55 60°C 0.68</p> <p><u>Solubility, gm/100 gm,</u> <u>at 25°C, in:</u></p> <p>Ether ∞ Alcohol ∞ 2:1 Ether:Alcohol ∞ Acetone ∞</p> <p><u>Viscosity, centipoises:</u></p> <p>Temp, 20°C 13.2</p> <p><u>Hydrolysis, % Acid:</u></p> <p>10 days at 22°C 0.032 5 days at 60°C 0.029</p>
<p><u>Heat of:</u></p> <p>Combustion, cal/gm 3428 Explosion, cal/gm 357 Gas Volume, cc/gm 851</p>	<p><u>Vapor Pressure:</u></p> <p>°C mm Mercury 25 < 0.001</p>

Origin:

Lourenco prepared triethylene glycol in 1863 by heating glycol with ethylene bromide in a sealed tube at 115°-120°C (Ann (3) 67, 275). Later in the same year Wurtz prepared triethylene glycol by heating ethylene oxide with glycol at 100°C. By action of nitric acid triethylene glycol was oxidized to $(H_2OOC \cdot CH_2 \cdot O \cdot CH_2)_2$ (Ann (3) 69, 331, 351).

The Germans and Italians were the first to prepare and use TEGN during World War II as an ingredient of rocket and propellant powders. The commercial production of TEGN in quantity is still difficult and its use as a plasticizer for nitrocellulose is being replaced by other liquid nitrates.

Preparation:

Triethylene glycol is purified by fractional distillation under vacuum in an 18-inch Vi-geaux fractioning column. The assembly as a whole is equivalent to 4.5 theoretical plates. The distillation is conducted using a 5 to 1 reflux ratio, at a pot temperature of approximately 180°C, and a take-off temperature of approximately 120°C.

The purified triethylene glycol (TEG) is nitrated by carefully stirring it into 2.5 parts of 65/30/5 nitric acid/sulphuric acid/water maintained at $0 \pm 5^\circ C$. The rate of cooling is sufficient that 300 gm of TEG can be added within 40 minutes. The mixture is stirred and held at $0 \pm 5^\circ C$, for 30 additional minutes. It is then drowned by pouring onto a large quantity of ice and extracted three times with ether. The combined extract is water-washed to a pH of about 4, shaken with an excess of sodium bicarbonate solution, and further washed with 1% sodium bicarbonate solution until the washings are colorless. The ethereal solution is water-washed until it has the same pH value as distilled water. It is carefully separated from excess water, treated with chemically pure calcium chloride to remove dissolved water, and filtered. The ether is removed by bubbling with dry air until a minimal rate of loss in weight is attained. The yield is 1.34 gm per gm TEG (84% of theoretical) and the nitrogen content of different batches range from 11.60 to 11.69% by the nitrometer method (calculated 11.67%).

References:⁷⁸

(a) See the following Picatinny Arsenal Technical Reports on TEGN:

<u>3</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>
1953	1745	1786	1767	1638
2193		2056	1817	

⁷⁸See footnote 1, page 10.

Composition: % Picric Acid 88 - 90 Mononitronaphthalene 12 - 10 C/H Ratio	Molecular Weight: 217	
	Oxygen Balance: CO ₂ % -62 CO % -14	
	Density: gm/cc	Cast 1.60
	Melting Point: °C 90	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 60 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 10 Sample Wt, mg	Boiling Point: °C Explodes 300	
	Refractive Index, n_{20}^D n_{25}^D n_{30}^D	
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 0.9 135°C 150°C	
Rifle Bullet Impact Test: Trials Explosions % 0 Partials 0 Burned 0 Unaffected 100	200 Gram Bomb Sand Test: Sand, gm 44.2	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 315 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.04	
	Ballistic Mortar, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs	Trauzl Test, % TNT:	
	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Detonation Rate: Confinement None Condition Cast Charge Diameter, in. 1.0 Density, gm/cc 1.60 Rate, meters/second 7020	
Flammability Index:		
Hygroscopicity: %		
Volatility:		

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones Hole Volume Hole Depth
	Color:
	Principal Uses: TNT substitute in projectiles and bombs
	Method of Loading: Cast
	Loading Density: gm/cc 1.60
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation Exudes at 50°C
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Preparation: Picric acid and alpha-mononitronaphthalene are melted together in an aluminum or tin steam-jacketed melt kettle equipped with a stirrer. Although picric acid alone requires a high temperature for its melt loading (120°C), the mixture forms a eutectic melting at 49°C. Care must be taken to prevent the formation of dangerous metallic picrates. Trimonite is of interest as an emergency substitute for TNT.

Origin:

Trimonite, a castable mixture of picric acid/mononitronaphthalene was developed by the British during World War II as an improvement over tridite which is a mixture of 80/20 picric acid/dinitrophenol. Both mixtures are suitable for melt-loading below 100°C and therefore represent an improvement over melt-loading picric acid alone (melting point 122°C). However, tridite is slightly inferior to picric acid as an explosive and dinitrophenol is objectionable because of its toxicity. Trimonite is also slightly inferior to picric acid and TNT as an explosive. Because of the low eutectic temperature of the picric acid-mononitronaphthalene mixture (49°C), Tridite exudes when stored at elevated temperatures. It does not possess the disadvantages of picric acid (corrosive action on metals, ease of decomposition, etc.) and is a comparatively inexpensive substitute for TNT.

References:⁷⁹

(a) See the following Picatinny Arsenal Technical Reports on Trimonite:

<u>2</u>	<u>5</u>	<u>6</u>	<u>8</u>
1352	1325	926	1098
1372		976	1838

⁷⁹See footnote 1, page 10.

Composition: % C 18.6 H 1.6 N 21.8 O 58.0 C/H Ratio 0.202 <div style="text-align: center;"> $\begin{array}{c} \text{O}-\text{CH}_2\text{C}(\text{NO}_2)_3 \\ \diagup \\ \text{C} = \text{O} \\ \diagdown \\ \text{CH}_2\text{CH}_2\text{C}(\text{NO}_2)_3 \end{array}$ </div>	Molecular Weight: (C ₆ H ₆ N ₆ O ₁₄) 386	
	Oxygen Balance: CO ₂ % -4.2 CO % 20.8	
	Density: gm/cc	Form I 1.78
	Melting Point: °C 93	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg 50% point, cm (a) 20	Boiling Point: °C	
	Refractive Index, n_D²⁰ Form I (e) <u>Crystal Axis</u> α 1.518 β 1.527 γ 1.546	
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C ---- 100°C 48 hrs 0.60 120°C 135°C 150°C	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm	
Explosion Temperature: °C Seconds, 0.1 (no cap used) --- 1 --- 5 50% point (Alhot bar) (a) 225 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	
	Ballistic Mortar, % TNT: (b) 136	
75°C International Heat Test: % Loss in 48 Hrs	Trauzl Test, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc 1.60 1.76 Rate, meters/second 7760 8290	
Flammability Index:		
Hygroscopicity: % 30°C, 90% RH 0.00 75°C, 5 months Nil (a)		
Volatility:		

Booster Sensitivity Test: Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc	Decomposition Equation: Oxygen, atoms/sec 4.4×10^{21} (Z/sec) Heat, kilocalorie/mole 43.4 (ΔH , kcal/mol) Temperature Range, °C Phase Liquid
Heat of: Combustion, cal/gm 1685 Explosion, cal/gm Gas Volume, cc/gm Formation, cal/gm 307 Fusion, cal/gm Sublimation, cal/gm (est) 804	Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bombs: Plate Thickness, inches 1 1¼ 1½ 1¾
Specific Heat: cal/gm/°C	Bomb Drop Test: T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete: Max Safe Drop, ft 500-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order 1000-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order
Burning Rate: cm/sec	
Thermal Conductivity: cal/sec/cm/°C	
Coefficient of Expansion: Linear, %/°C Volume, %/°C	
Hardness, Mohs' Scale:	
Young's Modulus: E', dynes/cm² E, lb/inch² Density, gm/cc	
Compressive Strength: lb/inch²	
Vapor Pressure: (e) °C mm Mercury 65 3.3×10^{-5} 75 1.3×10^{-4} 85 4.2×10^{-4} 100 2.3×10^{-3} 120 1.4×10^{-2}	

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Colorless Principal Uses: Method of Loading:
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Loading Density: gm/cc <div style="display: flex; justify-content: space-between;"> Form I 1.783 </div> <div style="display: flex; justify-content: space-between;"> Form II 1.677 </div> <div style="display: flex; justify-content: space-between;"> Liquid, 99°C, 1.551 </div>
Blast (Relative to H-6): <u>Sphere</u> <u>Cylinder (h)</u> Air: 1-lb Charge: <u>EW*</u> <u>EV*</u> <u>EW*</u> <u>EV*</u> Peak Pressure 0.91 0.84 0.81 0.75 Impulse 0.73 0.67 0.74 0.69 Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy *EW, equivalent weight of H-6 for a unit weight of test mixture for equal performance at the same test distance; EV, equivalent volume of H-6 for a unit volume of test mixture for equal performance at the same test distance.	Storage: <div style="display: flex; justify-content: space-between;"> Method Wet </div> Hazard Class (Quantity-Distance) Compatibility Group Exudation Bruceton Safety Test Results: (g) Mean and standard deviation of lengths of 0.300 diameter cylinder across which initiation is possible for 50% certainty: <div style="display: flex; justify-content: space-between;"> TNT 0.391 ± 0.040 </div> <div style="display: flex; justify-content: space-between;"> RDX Comp B 0.381 ± 0.042 </div> <div style="display: flex; justify-content: space-between;"> TNETB 0.920 ± 0.059 </div> Absolute Viscosity, poises: (e) <div style="display: flex; justify-content: space-between;"> Temp, 98.9°C 0.173 </div> <div style="display: flex; justify-content: space-between;"> 106.5°C 0.138 </div>

Solubility (Room Temperature):

(a)

Solvent	Solubility
Water	Insoluble
n-Hexane	Insoluble
Carbon tetrachloride	Insoluble
Ethanol	5 gm/100 gm solvent
Chloroform	5 gm/100 gm solvent
Benzene	10 gm/100 gm solvent
Nitromethane	Very soluble
Glacial acetic acid	Very soluble
Ethyl acetate	Very soluble

TNETB Forms Eutectics With the Following Compounds:

(a)

TNT	57
BTNES (bis(trinitroethyl) succinate)	80+
BTNEN (bis(trinitroethyl) nitramine)	68.5
TNB (trinitrobenzene)	65
Compound A ($C_4H_6N_4O_7$ formed by condensation of 1,1-dinitroethane)	77
Trinitroethyl trinitrobenzoate (27%)	80.5 (f)

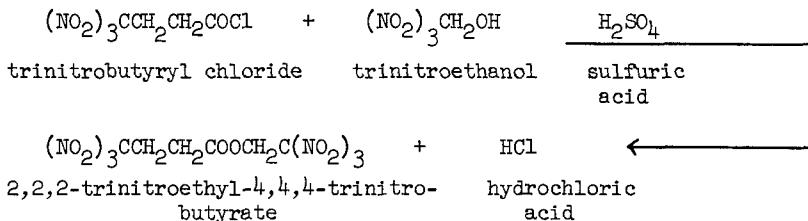
Crystallographic Data:

(a)

Three polymorphic crystalline forms have been observed. Low temperature Form I goes through a solid-solid transition at 89°C giving Form II. Form II has a melting point of 92.5° to 93°C. On cooling, Form II does not transform reversibly to Form I when 89°C is reached. However, Form II will transform to Form I at room temperature, usually taking a few hours to do so. Form III was observed, which appeared to be stable over a very narrow temperature range on the order of 0.2° to 0.3°C near 92.5°C.

Preparation:

(d)



Laboratory experiments indicate that the present slow step involving overnight treatment of 4,4,4-trinitrobutyryl chloride with 2,2,2-trinitroethanol and aluminum chloride can be replaced by a fast and simple esterification in sulfuric acid. Using 100% sulfuric acid or fortified H_2SO_4 , the ester can be prepared in yields of 95% to 98% in 24 hours at 25°C, in 5 hours at 50°C, or in 3 hours at 65°C. Above 65°C the reaction time is less, but the yield falls off and a less pure product is obtained. The crude white crystalline product on recrystallization from dilute methanol gives a material melting at 92° to 93°C.

Origin:

(e)

TNETB belongs to a new class of explosives characterized by trinitromethyl groups, $-C(NO_2)_3$. The chemistry of this class of compounds was studied in Germany by Drs. Schenck and Schimmelschmidt, who discovered in 1942-1943 that trinitromethane or nitroform, $HC(NO_2)_3$, was the source of new explosive derivatives. Dr. Schenck prepared the stable solid alcohol, 2,2,2-trinitroethanol, from nitroform and formaldehyde. Dr. Schimmelschmidt reacted nitroform with unsaturated organic compounds, such as acrylic acid, and predicted in 1943 that the ester of 4,4,4-trinitrobutyric acid with trinitroethanol would be an interesting explosive.

In 1947 the U.S. Navy began a program to explore these compounds. The initial task of investigating the chemistry of trinitroethanol was undertaken by the Hercules Powder Company (Navy Contract NOrd-9925). The U.S. Rubber Company studied the chemistry of nitroform (Navy Contract NOrd-10,129). After preparation of the first laboratory samples of TNETB, considerable interest was aroused. In early 1950 the Naugatuck Chemical Division of U.S. Rubber Company was assigned to prepare 100 pounds of TNETB. The Bureau of Ordnance in July 1953 raised the production to 800 pounds with the assistance of the Hercules Powder Company in augmenting the production at Naugatuck (Navy Contract NOrd-11,280). TNETB is a high oxygen content explosive.

References: ⁸⁰

(a) J. M. Rosen, Properties of Trinitroethyl Trinitrobutyrate TNETB, NAVORD Report No. 1758, 17 December 1950.

(b) Bureau of Mines Report No. 3107, Part IX, Ballistic Mortar Tests on Trinitroethyl Trinitrobutyrate, 5 April 1950.

(c) L. D. Hampton and G. Svadeba, Evaluation of 2,2,2-Trinitroethyl-4,4,4-Trinitrobutyrate as a Constituent of Castable Explosives, NAVORD Report No. 2614, 30 September 1952.

(d) U.S. Rubber Company Quarterly Progress Report No. 23, Synthesis of New Propellants and Explosives, Navy Contracts NOrd-10-129 and -12,663, 19 August 1953.

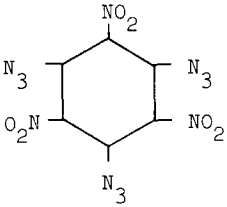
(e) M. E. Hill, O. H. Johnson, J. M. Rosen, D. V. Sickman and F. Taylor, Jr., Preparation and Properties of TNETB, a New Castable High Explosive, NAVORD Report No. 3885, 27 January 1955.

(f) M. E. Hill, Synthesis of New High Explosives, NAVORD Report No. 2965, 1 April 1953.

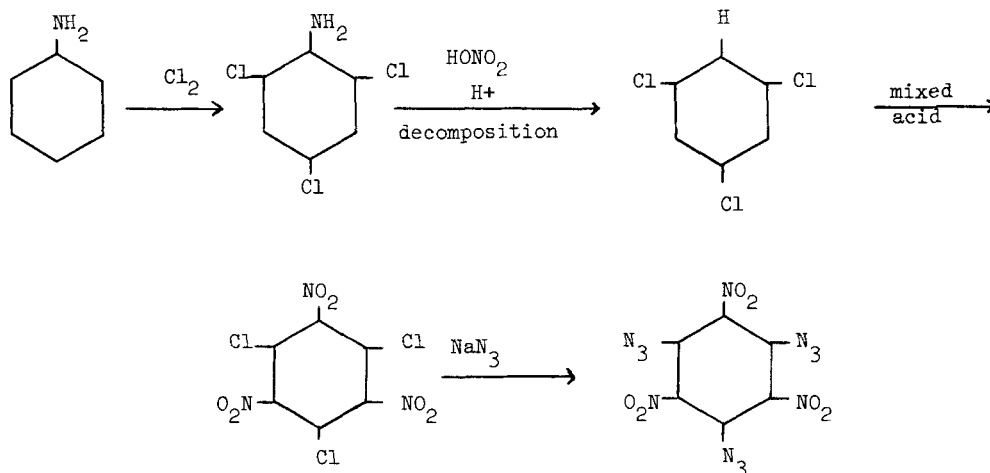
(g) Jacob Savitt, A Sensitivity Test for Castable Liquid Explosives, Including Results for Some New Materials, NAVORD Report No. 2997, 22 October 1953.

(h) R. W. Gipson, Sensitivity of Explosives, IX: Selected Physico-Chemical Data of Ten Pure High Explosives, NAVORD Report No. 6130, 18 June 1958.

⁸⁰See footnote 1, page 10.

Composition: % <div> <div>C 21.4</div> <div>N 50.0</div> <div>O 28.6</div> </div> <div> <div>C/H Ratio</div> </div> <div>  </div>		Molecular Weight: ($C_6O_6N_{12}$) 336
		Oxygen Balance: CO ₂ % -29 CO % 0.0
		Density: gm/cc Crystal 1.81
		Melting Point: °C Decomposes 131
		Freezing Point: °C
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm (a) ≤ 25 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg		Boiling Point: °C
		Refractive Index, n_{20}^D n_{25}^D n_{30}^D
Friction Pendulum Test: Steel Shoe Fiber Shoe		Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C
Rifle Bullet Impact Test: Trials % Explosions Partial Burned Unaffected		200 Gram Bomb Sand Test: Sand, gm
Explosion Temperature: °C (a) Seconds, 0.1 (no cap used) -- 1 -- 5 150 10 15 20		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl
		Ballistic Mortar, % TNT:
75°C International Heat Test: % Loss in 48 Hrs		Trauzl Test, % PETN: 90
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs		Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT
Flammability Index:		Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second
Hygroscopicity: % 30°C, 90% RH 0.00		
Volatility:		

<p>Fragmentation Test:</p> <p>90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments: For TNT For Subject HE</p> <p>3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments: For TNT For Subject HE</p>	<p>Shaped Charge Effectiveness, TNT = 100:</p> <p>Glass Cones Steel Cones</p> <p>Hole Volume</p> <p>Hole Depth</p> <p>Color: Greenish-yellow</p> <p>Principal Uses: (c) Ingredient of primer mix</p> <p>Method of Loading: Pressed Dead presses at about 42,000 psi</p> <p>Loading Density: gm/cc At 42,000 psi 1.75</p>										
<p>Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc</p>	<p>Storage:</p> <p>Method</p> <p>Hazard Class (Quantity-Distance)</p> <p>Compatibility Group</p> <p>Exudation None</p>										
<p>Blast (Relative to TNT):</p> <p>Air: Peak Pressure Impulse Energy</p> <p>Air, Confined: Impulse</p> <p>Under Water: Peak Pressure Impulse Energy</p> <p>Underground: Peak Pressure Impulse Energy</p>	<p><u>Qualitative Solubilities</u> <u>at Room Temperature:</u></p> <table> <tr> <th><u>Solvent</u></th><th><u>Solubility</u></th></tr> <tr> <td>Acetone</td><td>Readily soluble</td></tr> <tr> <td>Chloroform</td><td>Moderately soluble</td></tr> <tr> <td>Alcohol</td><td>Sparingly soluble</td></tr> <tr> <td>Water</td><td>Insoluble</td></tr> </table> <p><u>Compatibility with Metals:</u> <u>Wet:</u> Does not attack iron, steel, copper or brass.</p> <p><u>Heat of:</u></p> <p>Combustion, cal/gm (a) 2554</p> <p><u>Burning Rate:</u> (b)</p> <p>cm/sec 0.65</p>	<u>Solvent</u>	<u>Solubility</u>	Acetone	Readily soluble	Chloroform	Moderately soluble	Alcohol	Sparingly soluble	Water	Insoluble
<u>Solvent</u>	<u>Solubility</u>										
Acetone	Readily soluble										
Chloroform	Moderately soluble										
Alcohol	Sparingly soluble										
Water	Insoluble										

Preparation: (e)

Aniline is chlorinated to form trichloroaniline. The amino group is eliminated by the diazo reaction. The resulting sym-trichlorobenzene is nitrated. This nitration is carried out by dissolving the material in warm 32% oleum, adding strong nitric acid, and heating to 140°-150°C until no trinitro trichlorobenzene (melting point 187°C) precipitates (Ref f). The chlorine groups are then replaced by azo groups. This is accomplished by adding an acetone solution of the trinitro trichlorobenzene, or better, and powdered substance alone, to an actively stirred solution of sodium azide in alcohol. The precipitated trinitro triazidobenzene is collected on a filter, washed with alcohol, water and dried. It may be purified by dissolving in chloroform, allowing the solution to cool, and collecting the greenish yellow crystals (melting point 131°C with decomposition).

Origin:

This initiating explosive was first prepared in 1923 by Turek who also perfected its manufacture.

References:⁸¹

- (a) S. Helf, Tests of Explosive Compounds Submitted by Arthur D. Little, Inc., PATR 1750, 24 October 1949.
- (b) A. F. Belyaeva and A. E. Belyaeva CR a.s. USSR 52, 503-505 (1946) Chemical Abstracts 41, 4310.
- A. E. Belyaeva and A. F. Belyaeva, Doklady Akad Nauk. USSR 56, 491-494 (1947).
- (c) French Patent 893,941, 14 November 1944 (Chemical Abstracts 47, 8374).
- (d) A. D. Yoffe, "Thermal Decomposition and Explosion of Azides," Proc. Roy Soc A208, 188-199 (1951).
- (e) T. L. Davis, The Chemistry of Powder and Explosives, John Wiley and Sons, Inc., New York (1943), p. 436.
- (f) O. Turek, Chim et Ind 26, 781 (1931); German Patent 498,050; British Patent 298,981.

⁸¹See footnote 1, page 10.

Composition: % C 24.6 H 3.3 N 15.3 O 56.8 $ \begin{array}{c} \text{CH}_2\text{ONO}_2 \quad \text{CH}_2\text{ONO}_2 \quad \text{CH}_2\text{ONO}_2 \\ \quad \quad \\ \text{O}_2\text{NOCH}_2\text{CCH}_2\text{OCH}_2\text{CCH}_2\text{OCH}_2\text{CCH}_2\text{ONO}_2 \\ \quad \quad \\ \text{CH}_2\text{ONO}_2 \quad \text{CH}_2\text{ONO}_2 \quad \text{CH}_2\text{ONO}_2 \end{array} $ C/H Ratio 0.175	Molecular Weight: ($\text{C}_{15}\text{H}_{24}\text{N}_8\text{O}_{26}$) 732
	Oxygen Balance: CO ₂ % -35 CO % -2.2
	Density: gm/cc Crystal 1.58
	Melting Point: °C 82 to 84
	Freezing Point: °C
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 9 Sample Wt, mg 24	Boiling Point: °C
	Refractive Index, n_{20}^D n_{25}^D n_{30}^D
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C ---- 100°C Pure 2.45 120°C Specially purified 1.94 135°C 150°C
Rifle Bullet Impact Test: Trials % Explosions Partial Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm 58.9
Explosion Temperature: °C Seconds, 0.1 (no cap used) --- 1 --- 5 225 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate ---- Lead Azide 0.30 Tetryl ----
75°C International Heat Test: % Loss in 48 Hrs	Ballistic Mortar, % TNT:
100°C Heat Test: % Loss, 1st 48 Hrs 1.15 % Loss, 2nd 48 Hrs 0.75 Explosion in 100 Hrs None	Trauzl Test, % TNT:
Flammability Index:	Plate Dent Test: Method Condition Confined Density, gm/cc Brisanse, % TNT
Hygroscopicity: %	Detonation Rate: Confinement None Condition Pressed Charge Diameter, in. 0.5 Density, gm/cc 1.56 Rate, meters/second 7650
Volatility:	

Booster Sensitivity Test: Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc	Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH , kcal/mol) Temperature Range, °C Phase
Heat of: Combustion, cal/gm Explosion, cal/gm Gas Volume, cc/gm Formation, cal/gm Fusion, cal/gm	Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bombs: Plate Thickness, inches 1 1¼ 1½ 1¾
Specific Heat: cal/gm/°C <u>Specific Impulse:</u> lb-sec/lb (calculated)	Bomb Drop Test: T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete: Max Safe Drop, ft 500-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order 1000-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order
Burning Rate: cm/sec	
Thermal Conductivity: cal/sec/cm/°C	
Coefficient of Expansion: Linear, %/°C Volume, %/°C	
Hardness, Mohs' Scale:	
Young's Modulus: E', dynes/cm ² E, lb/inch ² Density, gm/cc	
Compressive Strength: lb/inch ²	
Vapor Pressure: °C mm Mercury	

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones Hole Volume Hole Depth																																							
	Color: White																																							
	Principal Uses: High explosive and as possible plasticizer for nitrocellulose																																							
	Method of Loading: Cast or pressed																																							
	Loading Density: gm/cc Pressed at 60,000 psi 1.565																																							
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Dry Hazard Class (Quantity-Distance) Compatibility Group Exudation None																																							
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Hygroscopicity, Gain or Loss in Wt, %: <table><tr><th rowspan="2">Time, Hrs</th><th colspan="3">% RH at 30°C</th></tr><tr><th>40</th><th>70</th><th>90</th></tr><tr><td>24</td><td>-0.008</td><td>+0.01</td><td>+0.04</td></tr><tr><td>48</td><td>-0.02</td><td>-0.01</td><td>+0.02</td></tr><tr><td>144</td><td>-0.04</td><td>-0.03</td><td>-0.02</td></tr><tr><td>192</td><td>-0.04</td><td>-0.02</td><td>-----</td></tr><tr><td>216</td><td>-0.004</td><td>-0.01</td><td>+0.03</td></tr></table> Solubility: <table><tr><th>Solvent</th><th>Solubility</th></tr><tr><td>Water</td><td>Insoluble</td></tr><tr><td>Alcohol</td><td>Soluble</td></tr><tr><td>Chloroform</td><td>Soluble</td></tr><tr><td>Acetone, hot</td><td>Very soluble</td></tr><tr><td>Benzene, hot</td><td>Very soluble</td></tr></table>	Time, Hrs	% RH at 30°C			40	70	90	24	-0.008	+0.01	+0.04	48	-0.02	-0.01	+0.02	144	-0.04	-0.03	-0.02	192	-0.04	-0.02	-----	216	-0.004	-0.01	+0.03	Solvent	Solubility	Water	Insoluble	Alcohol	Soluble	Chloroform	Soluble	Acetone, hot	Very soluble	Benzene, hot	Very soluble
Time, Hrs	% RH at 30°C																																							
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Solvent	Solubility																																							
Water	Insoluble																																							
Alcohol	Soluble																																							
Chloroform	Soluble																																							
Acetone, hot	Very soluble																																							
Benzene, hot	Very soluble																																							

Compatibility With Other High Explosives:100°C Vacuum Stability Test:

	NTN	PETN	RDX	TPEON
ml gas/40 hrs, 5 gm sample	0.14	2.15	0.39	2.45
ml gas/40 hrs, 5 gm sample of 50/50, TPEON/HE	1.89	1.71	2.32	—

Dipentaerythritol Hexanitrate (DPEHN)-TPEON Fusions:

% TPEON	% DPEHN	Solidification Time, Days	MP, °C
100	0	—	83
95	5	3	68
90	10	3	69
80	20	5	73
50	50	30	60 (Eutectic)
20	80	5	63
10	90	3	69
0	100	—	73

Preparation:

(a)

Twenty grams (0.054 mol) of nitration grade tripentaerythritol (TPE) (99% minimum purity) were slowly added, with stirring, to 160 gm (2.55 mol) of 99% nitric acid at a temperature of -25° to 0°C. On equivalent weight basis, this quantity of 99% nitric acid corresponds to an excess of 6.3 times the TPE used. After addition of the TPE, the reaction mixture was stirred for about one hour at 0° to 5°C and poured into eight times its volume of cracked ice. The product, when allowed to stand overnight, was crushed under water; filtered with suction; and washed copiously with water. It was then treated twice with about 5 times its weight of a 1% ammonium carbonate solution, stirred for several hours, filtered and washed with water until the final washings were neutral to litmus. The final product was washed successively with 50 cc each of ethanol and ether. The material dried in air weighed 37.8 gm or 96% of theory based on TPE. It had a melting range of 71° to 74°C. Crystallization of the crude TPEON from chloroform was found to be the most suitable method of obtaining pure TPEON.

Origin:

TPEON prepared by the reaction of tripentaerythritol and 99% nitric acid at 0° to 10°C was reported by Wyler in 1945 (J. A. Wyler to Trojan Powder Company: U.S. Patent 2,389, 228, 20 November 1945).

References:⁸²

- (a) J. J. LaMonte, H. J. Jackson, S. Livingston, L. B. Silberman and M. M. Jones, The Preparation and Explosive Properties of Tripentaerythritol Octanitrate, PATR No. 2490, 1958.
- (b) K. Namba, J. Yamashita and S. Tanaka, "Pentaerythritol Tetranitrate," J Ind Explosives Soc (Japan) 15, 282-9 (1954); CA 49, 11283 (1955).
- (c) S. D. Brewer and H. Henkin, The Stability of PETN and Pentolite, OSRD Report No. 1414.
- (d) E. Berlow, R. H. Barth and J. E. Snow, The Pentaerythritols, ACS Monograph No. 136, Reinhold Publishing Corporation, New York, 1958.

⁸²See footnote 1, page 10.

Composition:		Molecular Weight:		81
%		Oxygen Balance:		
TNT	80	CO ₂ %	-77	
Aluminum	20	CO %	-38	
C/H Ratio		Density: gm/cc	Cast	1.72
		Melting Point: °C		
		Freezing Point: °C		
Impact Sensitivity, 2 Kg Wt:		Boiling Point: °C		
Bureau of Mines Apparatus, cm	85	Refractive Index, n_{20}^D n_{25}^D n_{30}^D		
Sample Wt 20 mg				
Picatinny Arsenal Apparatus, in.	13			
Sample Wt, mg	16			
Friction Pendulum Test:		Vacuum Stability Test:		
Steel Shoe	Unaffected	cc/40 Hrs, at		
Fiber Shoe	Unaffected	90°C		
Rifle Bullet Impact Test:		100°C		0.1
	Trial	120°C		0.2
Explosions	%	135°C		--
Partial	60	150°C		0.8
Burned	0			
Unaffected	40	200 Gram Bomb Sand Test:		
Explosion Temperature: °C		Sand, gm		
Seconds, 0.1 (no cap used)	610	Sensitivity to Initiation:		
1	520	Minimum Detonating Charge, gm		
5 Decomposes	470	Mercury Fulminate		
10	465	Lead Azide		0.20
15		Tetryl		0.10
20				
75°C International Heat Test:		Ballistic Mortar, % TNT:	(a)	124
% Loss in 48 Hrs		Trauzl Test, % TNT:	(b)	125
100°C Heat Test:		Plate Dent Test:	(c)	
% Loss, 1st 48 Hrs		Method		B
% Loss, 2nd 48 Hrs		Condition		Cast
Explosion in 100 Hrs		Confined		No
		Density, gm/cc		1.75
		Brisance, % TNT		93
Flammability Index:	100	Detonation Rate:		
Hygroscopicity: % 30°C, 90% RH	0.00	Confinement	None	None
Volatility:		Condition	Cast	Pressed
		Charge Diameter, in.	1.0	1.0
		Density, gm/cc	1.71	1.72
		Rate, meters/second	6475	6700

Booster Sensitivity Test: (d) Condition Cast Tetryl, gm 100 Wax, in. for 50% Detonation 0.58 Wax, gm Density, gm/cc 1.75	Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH, kcal/mol) Temperature Range, °C Phase																														
Heat of: (c) Combustion, cal/gm 4480 Explosion, cal/gm 1770 Gas Volume, cc/gm Formation, cal/gm Fusion, cal/gm	Armor Plate Impact Test: (e) 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec 509 >1100 Aluminum Fineness 100 12 500-lb General Purpose Bombs: <table><tr><td>Plate Thickness, inches</td><td><u>Trials</u></td><td><u>% Inert</u></td></tr><tr><td>1</td><td>0</td><td></td></tr><tr><td>1¼</td><td>6</td><td>100</td></tr><tr><td>1½</td><td>6</td><td>33</td></tr><tr><td>1¾</td><td>0</td><td></td></tr></table>	Plate Thickness, inches	<u>Trials</u>	<u>% Inert</u>	1	0		1¼	6	100	1½	6	33	1¾	0																
Plate Thickness, inches	<u>Trials</u>	<u>% Inert</u>																													
1	0																														
1¼	6	100																													
1½	6	33																													
1¾	0																														
Specific Heat: cal/gm/°C (b) At -5°C 0.23 Density, gm/cc 1.74 At 20°C 0.31																															
Burning Rate: cm/sec																															
Thermal Conductivity: cal/sec/cm/°C (b) 11 x 10 ⁻⁴ Density, gm/cc 1.73																															
Coefficient of Expansion: Linear, %/°C Volume, %/°C																															
Hardness, Mohs' Scale:																															
Young's Modulus: (b) E', dynes/cm ² 6.67 x 10 ¹⁰ E, lb/inch ² 0.97 x 10 ⁶ Density, gm/cc 1.72																															
Compressive Strength: lb/inch ² (b) 2340 Density, gm/cc 1.75																															
Vapor Pressure: °C mm Mercury																															
	Bomb Drop Test: (e) T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete: Max Safe Drop, ft 500-lb General Purpose Bomb vs Concrete: <table><tr><td></td><td><u>Seal</u> 4,000</td><td><u>Seal</u> 5,000</td></tr><tr><td>Height, ft</td><td></td><td></td></tr><tr><td>Trials</td><td>34</td><td>14</td></tr><tr><td>Unaffected</td><td>32</td><td>14</td></tr><tr><td>Low Order</td><td>0</td><td>0</td></tr><tr><td>High Order</td><td>2</td><td>0</td></tr></table> 1000-lb General Purpose Bomb vs Concrete: <table><tr><td></td><td><u>Seal</u> 5,000</td></tr><tr><td>Height, ft</td><td></td></tr><tr><td>Trials</td><td>24</td></tr><tr><td>Unaffected</td><td>23</td></tr><tr><td>Low Order</td><td>0</td></tr><tr><td>High Order</td><td>1</td></tr></table>		<u>Seal</u> 4,000	<u>Seal</u> 5,000	Height, ft			Trials	34	14	Unaffected	32	14	Low Order	0	0	High Order	2	0		<u>Seal</u> 5,000	Height, ft		Trials	24	Unaffected	23	Low Order	0	High Order	1
	<u>Seal</u> 4,000	<u>Seal</u> 5,000																													
Height, ft																															
Trials	34	14																													
Unaffected	32	14																													
Low Order	0	0																													
High Order	2	0																													
	<u>Seal</u> 5,000																														
Height, ft																															
Trials	24																														
Unaffected	23																														
Low Order	0																														
High Order	1																														

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc 1.71 Charge Wt, lb 2.272 Total No. of Fragments: For TNT 703 For Subject HE 616 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc 1.73 Charge Wt, lb 0.914 Total No. of Fragments: For TNT 514 For Subject HE 485	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones Hole Volume Hole Depth Color: Gray Principal Uses: GP bombs Method of Loading: Cast Loading Density: gm/cc 1.65-1.72
Fragment Velocity: ft/sec At 9 ft 2460 At 25½ ft 2380 Density, gm/cc 1.72	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation
Blast (Relative to TNT): (f) Air: Peak Pressure 110 Impulse 115 Energy 119 Air, Confined: Impulse 130 Under Water: Peak Pressure 105 Impulse 118 Energy 119 Underground: Peak Pressure 117 Impulse 127 Energy 136	Preparation: Tritonal is prepared by adding TNT and aluminum separately to a steam-jacketed melt kettle equipped with a stirrer. Heating of the kettle and mixing of the ingredients are continued until all the TNT is melted. When the viscosity of the mixture is considered satisfactory (about 85°C), the tritonal is poured into projectiles or bombs the same as TNT.

Origin:

The Addition of aluminum to increase the power of explosives was proposed by Escales in 1899 and patented by Roth in 1900 (German Patent 172,327). Some recent studies, directed towards establishment of the optimum amount of aluminum in the TNT/Aluminum system, have shown that (1) the blast effect increases to a maximum when the aluminum content is 30% (Ref g); the brisance, as measured by the Sand Test, passes through a maximum at about 17% aluminum (Ref h); in Fragmentation Tests, no maximum is observed, additions of aluminum causing a decrease in efficiency over the entire range from 0% to 70% aluminum (Ref i); and (4) the rate of detonation of cast charges is continuously decreased by additions of aluminum up to 40% (Ref j). For all practical purposes it is concluded that the addition of 18% to 20% aluminum to TNT improves its performance to a maximum. This conclusion is in agreement with that of British workers who measured performance of aluminized TNT-mixtures based on extensive Lead Block Test data (Ref k).

Tritonal, consisting of 80% TNT and 20% aluminum, was developed and standardized in the United States during World War II for use in bombs.

References:⁸³

- (a) L. C. Smith and E. H. Eyster, Physical Testing of Explosives, Part III, Miscellaneous Sensitivity Tests, Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.
- (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (d) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Teteryl in Boosters, NOL Memo 10,303, 15 June 1949.
- (e) Committee of Div 2 and 8, NDRC, Report on HBX and Tritonal, OSRD No. 5406, 31 July 1945.
- (f) W. R. Tomlinson, Jr., Blast Effects of Bomb Explosives, PA Tech Div Lecture, 9 April 1948.
- (g) W. B. Kennedy, R. F. Arentzen and C. W. Tait, Survey of the Performance of TNT/Al on the Basis of Air-Blast Pressure and Impulse, OSRD Report No. 4649, Division 2, Monthly Report No. AES-6, 25 January 1945.
- (h) W. R. Tomlinson, Jr., Develop New High Explosive Filler for AP Shot, PATR No. 1290, First Progress Report, 19 May 1943.
- (i) W. R. Tomlinson, Jr., Develop New High Explosive Filler for AP Shot, PATR No. 1380, Second Progress Report, 12 January 1944.
- (j) L. S. Wise, Effect of Aluminum on the Rate of Detonation of TNT, PATR No. 1550, 26 July 1945.
- (k) Armament Research Dept, The Effect of Aluminum on the Power of Explosives, British Report AC-6437, May 1944 (Explosives Report 577/44).

⁸³See footnote 1, page 10.

(1) Also see the following Picatinny Arsenal Technical Reports on Tritonal:

<u>0</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>
1530	1693	1444	1635	1956	1737	2138
1560	2353				2127	
2010						

Veltex No. 448*

AMCP 706-177

Composition:		Molecular Weight: 281	
% HMX	70.0	Oxygen Balance:	
Nitrocellulose (13.15% N)	15.0	CO ₂ %	-26
Nitroglycerin	10.7	CO %	-0.5
2-Nitrodiphenylamine	1.3	Density: gm/cc Pressed 1.72	
Triacetin	3.0	Melting Point: °C	
C/H Ratio		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt:		Boiling Point: °C	
Bureau of Mines Apparatus, cm		Refractive Index, n_{20}^D	
Sample Wt 20 mg		n_{25}^D	
Picatinny Arsenal Apparatus, in.		n_{30}^D	
Sample Wt, mg		Vacuum Stability Test:	
Friction Pendulum Test:		cc/40 Hrs, at	
Steel Shoe	Unaffected	90°C	
Fiber Shoe	Unaffected	100°C	
Rifle Bullet Impact Test: Trials		120°C 29 hours	
	%	135°C	
Explosions		150°C	
Partials		200 Gram Bomb Sand Test:	
Burned		Sand, gm	
Unaffected		66.4	
Explosion Temperature: °C		Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)		Minimum Detonating Charge, gm	
1		Mercury Fulminate	
5		Lead Azide	
10		Tetryl	
15		Ballistic Mortar, % TNT:	
20		Trauzl Test, % TNT:	
75°C International Heat Test:		Plate Dent Test:	
% Loss in 48 Hrs		Method	
90 °C Heat Test:		Condition	
% Loss, 1st 48 Hrs	0.28	Confined	
% Loss, 2nd 48 Hrs	1.12	Density, gm/cc	
Explosion in 100 Hrs	None	Brisance, % TNT	
Flammability Index:		Detonation Rate:	
Hygroscopicity: %		Confinement	
Volatility:		Condition	
		Charge Diameter, in.	
		Density, gm/cc	
		Rate, meters/second (calculated)	
		8500	

*See footnote on following page.

Booster Sensitivity Test: Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc	Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH , kcal/mol) Temperature Range, °C Phase
Heat of: Combustion, cal/gm 2359 Explosion, cal/gm 1226 Gas Volume, cc/gm Formation, cal/gm Fusion, cal/gm	Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bombs: Plate Thickness, inches 1 1¼ 1½ 1¾
<u>Compression at Rupture:</u> % 8.26 <u>Work to Produce Rupture:</u> ft-lb/inch ³ 9.62	
Burning Rate: cm/sec	
Thermal Conductivity: cal/sec/cm/°C	
Coefficient of Expansion: Linear, %/°C Volume, %/°C	
Hardness, Mohs' Scale:	
Young's Modulus: E', dynes/cm ² 0.24×10^{10} E, lb/inch ² 0.35×10^5 Density, gm/cc	
Compressive Strength: lb/inch ² 2720	
Vapor Pressure: °C mm Mercury	Bomb Drop Test: T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete: Max Safe Drop, ft 500-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order 1000-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order
*Name assigned by Dr. Mark M. Jones, formerly of PA; based on original development by James H. Veltman.	

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Color: Orange
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Principal Uses: High mechanical strength machinable explosive
	Method of Loading: Pressed
	Loading Density: gm/cc At 6,700 psi 1.72
	Storage: Method Dry Hazard Class (Quantity-Distance) Compatibility Group Exudation None Machinability Excellent

Preparation:

The preparation of this class of explosive compositions is illustrated by the method used for Veltex No. 448: Place 675 cc of water in a slurry kettle equipped with an agitator. Add 5.85 gm of 2-nitrodiphenylamine and agitate for several minutes to obtain dispersion. Then add 93.7 gm of water-wet nitrocellulose (dry weight 67.5 gm) in small portions. Raise the temperature to 48°C and maintain this temperature, but continue the agitation. A mixture of 48.2 gm of nitroglycerin and 13.5 gm of triacetin is added over a 5-minute period, with the mixing continuing for an additional 10 minutes at 48°C. The HMX (350 gm) is added over a 5-minute period with agitation continued for 30 minutes at 48°C. The slurry is cooled to room temperature and filtered. The filter cake is dried to a moisture content between 8% and 12%. The incorporation of this mix is completed by rolling 50 gm portions at a temperature of approximately 90°C. The finished colloid is then preheated on a heat table at 66°C. Increments of 25 gm each are pressed at 6700 psi for four minutes at 71°C. A cylinder is then built up by pressing together four 25 gm increments for a dwell time of 15 minutes.

Origin:

Veltex is the name given to a series of closely related nitrocellulose compositions prepared in 1957 at Picatinny Arsenal by the solventless process used for propellants. These compositions all contain a high percentage of solid high explosive. They were investigated to determine the suitability of the Holtex type explosive developed by Hispano Suiza of Switzerland, France and Spain, but for which the composition was not reported (Ref a). Compositions similar to Veltex No. 448 and containing 60% to 80% HMX, with either nitroglycerin or triethyleneglycol dinitrate as colloidizing agent for nitrocellulose, have also been prepared. In general these compositions showed lower heat stability than that of conventional high explosive compositions.

Reference:⁸⁴


(a) U.S. Air Intelligence Information Report IR-269-55, Holtex--Hispano Suiza Explosive, 4 May 1955.

⁸⁴See footnote 1, page 10.

(AMCRD-TV)

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